Report No. FAA DS-68-19

FINAL REPORT

Project No. 560-004-03H
Contract No. FA67WA-1810

EVALUATION OF ANGLE OF ATTACK INSTRUMENTATION IN THE TRAINING OF STUDENT PILOTS TO PRIVATE PILOT CERTIFICATION

August, 1968

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Aircraft Development Service
Washington D.C.

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Prepared by:

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ABSTRACT

An evaluation of the effectiveness of angle-of-attack instrumentation in the training of student pilots to private pilot certification was conducted by comparing flight performances and other related measures between a control group and an experimental group. The experimental group differed only in that they would use angle-of-attack information in addition to airspeed.

Such measures as time to first solo, total hours, overall performance in three flight checks failed to indicate any significant differences between the groups. When the flight check performances were analyzed by maneuver, significant differences did appear in favor of the angle-of-attack group in the performance of slow flight, downwind leg for normal landings, and final approach for short-field landings.

Flight performance data and results are open to question inasmuch as the experimental students were permitted to use both the angle of attack and the airspeed indicators. Although emphasis was placed on angle of attack until solo, rate of learning of the experimental students was affected by the need to teach and transition the student to the use of airspeed information.

The use of angle-of-attack instrumentation requires new instructional techniques and a new training syllabus. The teaching and use of angle-of-attack information enhances the intellectual understanding of basic aerodynamics and aircraft control. Reliable angle-of-attack instrumentation also emphasizes the limitations of airspeed information in determining optimum aircraft performance.

It is recommended that evaluation of angle-of-attack instrumentation in the training of student pilots be continued using an experimental design which can discriminate between the effectiveness of angle-of-attack and airspeed instrumentation.

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INTRODUCTION

PURPOSE

How good is angle-of-attack information and what is its value in the training of general aviation pilots?

To answer these questions an experimentation program was designed and carried out by the Department of Aviation of The Ohio State University for the Aircraft Development Service of the Federal Aviation Administration.

The express purpose of the experimentation program was to evaluate the effectiveness of angle-of-attack instrumentation in the training of student pilots to private pilot certification. This report documents the program and presents the findings, conclusions, and recommendations.

GUIDELINES AND OBJECTIVES

Listed below are the basic quidelines for the experimentation program as provided by the FAA.

1. Fifteen students shall be selected as an experimental group for training in an aircraft using an angle-of-attack instrument display, and fifteen students selected as a control group for training using the current required flight instrumentation for general aviation aircraft.

2. Experimental group students shall be trained to the required performance for a private pilot certificate using the angle-of-attack instrument in addition to the airspeed. The normal syllabus sequence shall be used under as uniform conditions as possible for each student in both groups.

3. Students will proceed at their individual pace rather than being handled as a class group.

4. The performances of students in the experimental group shall be compared to performances of students in the control group.

With the preceding guidelines in mind, the objectives proposed for the experimental program were to determine answers to the following specific questions.

A. Does angle-of-attack instrumentation facilitate flight training?

B. If so, to what measurable degree can this be shown?

C. Specifically, in which aspects of the student flight program is there a significant difference of performance?

D. Would the use of angle-of-attack instrumentation require new instructional techniques and revision of the currently traditional training syllabus?

E. Could the use of angle-of-attack instrumentation lead to revised standards for private pilot proficiency?

F. What disadvantages and problems are incurred through the use of angle-of-attack instrumentation?

G. What insights can be gleaned from the experiments from which future research may profit?

BACKGROUND

Although the concept of angle of attack is fundamental in the aerodynamics of all aircraft, one should not be surprised to learn that pilots have been taught to fly aircraft with little or no knowledge of the role of angle of attack. To better understand why this is so, some historical explanations would be appropriate.

The concept of angle of attack was recognized by the early pioneers in aeronautics as basic to the understanding of lift and lift efficiency. Attempts to measure angle of attack go back to Wilbur and Orville Wright who used an angle-of-incidence indicator in their early experiments. But, characteristically, state-of-the-art lags state-of-the-mind. The technical development of angle-of-attack devices has been fraught with problems of reliability, accuracy, sensor dynamics, displays, and, to a large extent, subjective opinions. Furthermore, as the airplane began to develop, greater emphasis was placed on speed rather than lift efficiency, hence the development and use of the airspeed indicator as a flight control instrument.

In this country two organizations contributed greatly to a quantitative understanding of angle of attack. The forerunner to the CAA, as early as 1918, began studying ways of providing stall warning because of the large number of accidents which resulted from stalls. NACA, on the other hand, was using angle-of-attack devices for recording flight data. In 1941 CAA and NACA combined their investigations. Their findings showed that the stall was a function of angle of attack and not airspeed. Tests by the CAA in 1944 confirmed earlier tests by United Airlines that airspeed at the stall point was a function of the flight configuration, whereas angle of attack remained relatively constant (i.e., independent of flight configuration).

Active interest in the development of angle-of-attack devices began in 1946 when AMC began an extensive series of flight tests. Initial

interest was in their use for airborne rocket-launching systems. Summaries of these tests and subsequent development of the angle of attack as a flight control instrument are excellently described in Reference 16.* For a historical development prior to 1946, Reference 13 is recommended.

In recent years, angle-of-attack information has been widely touted by the U. S. Navy for use during carrier landings and specific aircraft configurations. More recently, interest has been shown in the operation of large jet aircraft to determine optimum pitch attitude just after rotation.[15] The U. S. Air Force has shown positive interest in the use of angle-of-attack information on STOL aircraft.[2] Even today's executive business jets are experimenting with angle-of-attack devices for improving pilot performance during high-altitude maneuvers as well as in the landing phase.[1] As the state-of-the-art improved so has acceptance of angle-of-attack devices.

The present use of the airspeed indicator to verify climb and approach attitudes, let alone stalls, is traditional. Ignorance as to the meaning of angle of attack in aircraft performance appears to characterize the novice pilot. The student is taught to control airspeed with pitch attitude (for constant power) and that "certain airspeeds are proper" and airspeeds "much lower" are to be avoided! His corresponding visual reference is his aircraft attitude with respect to the natural horizons.

Today's training aircraft are becoming larger, faster, heavier, and more complex. In the landing phase (during which most of today's accidents occur) the student must learn a wide range of airspeeds, depending on the aircraft load and configuration; even then he exhibits great uncertainty as to his margin of safety from the stall. His outside references tend to deceive him, particularly when he is unable to coordinate his descent with throttle control. His awareness of any increased rate of descent (and hence, increased angle of attack) is not well developed. At night this awareness is many times more difficult.

Thus there exists a growing body of evidence that "angle of attack" should be used as a flight control instrument. But up to this time, there has been conspicuously little information on the use of angle-of-attack information in the training of student pilots. It would seem that for the student pilot, there always exists the need for unambiguous verification of the proper aircraft attitude whenever in a high angle-of-attack maneuver, such as short-field landings and take offs, slow flight, or stalls.

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*A listing of references is given in Appendix A.

THE EXPERIMENTAL PLAN

The experimentation program was orginally designed to be carried out during the Autumn quarter (October - December, 1967) with approximately 15 to 18 matched pairs of students. Each student of the matched pair was to be randomly chosen for the control group or the experimental group. However, a concurrent and independent experimentation program for the FAA resulted in considerable modification of the angle-of-attack program. In particular, the resulting selection and numbers of students required the program to be conducted over both the Autumn and Winter academic quarters. The following description of the angle-of-attack program is based on smaller experimental and control groups in Autumn quarter (labeled EA and CA, respectively) and a similarly composed pair of groups (EW and CW) in the Winter quarter.

STUDENT SELECTION

Each student completed a background questionnaire (Appendix H) and most of the students completed a battery of aptitude and personality tests (Appendix O). Assignment of the students was randomly made into the experimental or control group. The composition of each group is shown in Tables I - IV.

INSTRUCTOR ORIENTATION AND ASSIGNMENT

Orientation and assignment of flight instructors was the responsibility of the Chief Flight Instructor. An orientation lecture was given to all flight instructors, as was individual demonstration and practice flights. Considerable difficulty was initially encountered by the instructors regarding both the use of the instrument and how to effectively teach with it. These difficulties were further compounded by a series of maintenance and reliability problems occurring during the Autumn Quarter. These problems will be discussed in detail later in the report. By the beginning of the Winter academic quarter, the angle-of-attack system was replaced by a much improved system which proved to be completely reliable and trouble free.* Also at the beginning of the Winter quarter, a training manual was developed and issued to each instructor and student in the experimental group. (This training manual comprises Appendix B.)

It was intended to assign at least one experimental and one control student to each instructor. A summary of flight instructors' qualifications is presented in Tables V and VI.

*Description of the angle-of-attack instrumentation is presented on pages 13-19.

Table I

Summary - Student Characteristics - Control Group Autumn Quarter

Student	C1	C2	C3	C4	C5	C6	C7	C8
Age	22	21	22	21	20	20	22	21
College Subject Major	Lib. Arts	Lib. Arts	Comm.	Comm.	Lib. Arts	Econ.	Sci.	Engrng.
Flight Experience (in hours)								
As A Student	0	0	5	0	0	0	1	0
As A Passenger	0	50	3	45	0	20	3	0
Written Aptitude Tests								
Flanagan ACT								
Test 1	-	76	64	60	51	58	66	45
Test 7	-	19	22	18	22	23	20	23
Test 9	-	21	30	26	22	30	30	20
Test 15	-	29	28	21	32	27	33	31
Otis:Gamma	-	129	121	118	124	130	116	123
Owens-Bennett	-	45	42	34	42	27	33	31

Table II

Summary - Student Characteristics - Experimental Group Autumn Quarter

Student	E1	E2	E3	E4	E5	E6	E7	E8
Age	21	22	21	20	22	22	21	21
College Subject Major	Engrng.	Lib. Arts	Agric.	Food Tech.	Comm.	Ed.	Engrng.	Ed.
Flight Experience (in hours)								
As A Student	10	0	2	0	0	0	0	0
As A Passenger	10	0	6	10	4	0	2	4
Written Aptitude Tests								
Flanagan ACT								
Test 1	65	60	-	52	51	62	63	53
Test 7	20	18	-	22	22	18	14	21
Test 9	31	28	-	28	30	26	30	32
Test 15	32	29	-	19	34	23	25	29
Otis:Gamma	128	115	-	121	108	127	119	111
Owens-Bennett	51	37	-	39	33	37	38	45

Table III

Summary - Student Characteristics - Control Group Winter Quarter

Student	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
Age	20	21	33	22	21	20	20	18	21	25
College Subject Major	Ed.	Math.	Comm.	Lib. Arts	Comm.	Lib. Arts	Ed.	Agric.	Sci.	Engnrng.
Flight Experience (in hours)										
As A Student	1	0	20	3	0	0	4	0	0	0
As A Passenger	0	0	55	10	0	5	60	5	3	10
Written Aptitude Tests										
Flanagan ACT										
Test 1	46	37	48	59	-	52	-	57	53	-
Test 7	19	18	21	22	-	18	-	19	21	-
Test 9	24	27	27	32	-	28	-	30	32	-
Test 15	16	23	24	18	-	30	-	29	25	-
Otis:Gamma	103	127	109	123	-	128	-	117	126	-
Owens-Bennett	31	27	37	46	-	40	-	47	46	-

Table IV

Summary - Student Characteristics - Experimental Group Winter Quarter

Student	E9	E10	E11	E12	E13	E14	E15	E16	E17
Age	21	20	23	22	21	22	21	22	19
College Subject Major	Comm.	Agric.	Engrng.	Engrng.	Comm.	Agric.	Comm.	Lib. Arts	Engrng.
Flight Experience (in hours)									
As A Student	0	0	0	0	0	0	0	0	0
As A Passenger	0	2	0	10	0	10	20	3	35
Written Aptitude Tests									
Flanagan ACT									
Test 1	43	70	62	61	54	53	53	64	46
Test 7	17	22	22	21	21	19	20	23	21
Test 9	27	21	26	21	22	28	29	29	21
Test 15	35	32	30	35	23	29	24	29	27
Otis:Gamma	115	112	120	125	105	124	110	130	126
Owens-Bennet	54	45	49	43	37	50	35	39	44

Table V

Summary - Flight Instructor Qualifications
Autumn Quarter

	Instructor											
	1	2	3	4	5	6	7	8	9	10	11	12
Control Students	C2	C4	*	*		C6	C5	C3	C7 C8	C1		
Experimental Students	E5 E3	E4	*	*	E1 E2		E6		E7		E8	
												Mean
Age	20	23	28	23	19	28	22	29	25	22	37	25
Total Flight Hours	350	375	2500	950	900	325	1100	1375	650	420	1500	950
Total Instructional Hours	80	110	1900	650	450	80	670	775	300	120	800	540
Pilot Licenses												
ATR			X									
Commercial - Airplane, Land	X	X	X	X	X	X	X	X	X	X	X	
Single Engine	X	X	X	X	X	X	X	X	X	X	X	
Multi-Engine			X	X	X	X	X	X	X	X		
Instruments			X	X	X	X	X	X	X		X	
Flight Instructor												
Airplanes	X	X	X	X	X	X	X	X	X	X	X	
Instruments			X	X	X		X				X	
Ground Instructor												
Basic										X		
Advanced			X	X		X					X	
Instruments			X	X		X					X	
Marital Status	S	S	M	S	S	S	M	S	M	S	M	
Male or Female	M	F	M	F	M	M	M	M	M	M	M	

* Students unable to complete program

Table VI

Summary - Flight Instructor Qualifications
Winter Quarter

	Instructor 12	13	14	15	16	1	2	Mean
Control Students	C17 C18	C9 C16	C12	C10	C13	C14 C15	C11	
Experimental Students	E17	E15	E10	E12 E13	E6 E14 E2	E9	E11 E16	
Age	24	19	21	23	27	20	23	22
Total Flight Hours	545	980	450	360	1050	450	530	624
Total Instructional Hours	175	500	200	120	300	160	260	245
Pilot Licenses								
ATR								
Commercial - Airplane, Land	X	X	X	X	X	X	X	
Single Engine	X	X	X	X	X	X	X	
Multi-Engine		X			X			
Instruments	X	X	X	X	X			
Flight Instructor								
Airplanes	X	X	X	X	X	X	X	
Instruments								
Ground Instructor								
Basic								
Advanced								
Marital Status	S	S	S	S	S	S	S	
Male or Female	M	M	M	F	M	M	F	

The program of flight training used in both the experimental and control groups was to follow closely the approved syllabus (Appendix C). This program allows the student to proceed at his own pace. Encouragement was given to all instructors to introduce short-field landings well before the Stage II flight check. There were no major changes in the program for the experimental group.

Flight checks were given to all students at scheduled intervals. A minimum of three flight checks were used for the angle-of-attack program. The first check, or Stage I check, occurred between 9 and 13 hours. A Stage II check was given at about the 20-hour point. The final flight check was either the ROTC final evaluation ride or the private pilot certification ride. In the case of the experimental students, their final flight checks were repeated, during which a set of selected maneuvers was flown without the use of the angle-of-attack system. The flight profiles for each flight check are described in Appendix D.

The Stage I and II flight checks were administrated by the Chief Flight Instructor and his assistant, both FAA approved school examiners. The final flight check was almost entirely done by one of two FAA designated examiners.

DATA COLLECTION

The primary source of data for comparison of the experimental and control groups was the use of Pilot Performance Description Records (PPDR)* (a sample set appears in Appendix E). The underlying concept of the PPDR is that the check pilot consistently follows a well-defined procedure and uses a scoring system which attempts to describe what the student pilot did. For example, the maneuvers are broken down into segments, each segment being characterized by a set of important parameters; i.e., airspeed, pitch and bank attitudes, altitude, and heading (or track). Scales have been developed for each parameter, allowing the check pilot to quickly indicate an approximate or exact value for the parameter. Deviations from the desired values form a quantitative basis of measurement of the student's skill. Of course there are some maneuvers or aspects of the private pilot standards for which numbers are not available, such as judgment, emergency planning, coordination, technique, communications, etc. In these cases, scales can still be used but they are highly subjective.

The scoring of the PPDR was based on a set of standards developed by the senior staff. Each item on the PPDR had an error value, with the desired performance scored as zero error. The total scores for each

* The concept of the Pilot Performance Description Records was developed by the Human Resources Research Office (HumRRO) at Fort Rucker, Alabama, in the evaluation of Army helicopter pilot training.[4,9,10]

maneuver reflected the deviations from standard; the lower the error score the better the performance.

Other data collected during the program consisted of questionnaires and progress reports. Each instructor was asked to evaluate his student and the angle-of-attack instrumentation (Questionnaire #2, Appendix K). This questionnaire was also used to assess instructor standards for various relevant maneuvers and compliance with the training syllabus.

At the end of the program each student was asked to complete a questionnaire (Appendix J) which attempted to assess his aeronautical knowledge of angle of attack and, at this same time, to obtain his opinions of the angle-of-attack instrumentation.

Related data on malfunctions, maintenance and weather were collected. Monthly progress reports listed student progress and instructional difficulties. Such weather data as ceilings, visibility, and wind velocity are summarized in Appendix G.

DESCRIPTION OF THE INSTRUMENTATION

The angle-of-attack instrumentation used in this program was manufactured by the Monitair Corporation, Teterboro, N. J. The system is to provide the pilot with a positive visual indication of the angle of attack of the aircraft's wing and also to alert the pilot of an impending stall. A complete system has been installed on each of three Piper Cherokee 140's belonging to The Ohio State University Department of Aviation. The four elements comprising each system are listed below.

1. Wing transmitter (or vane) assembly. This assembly replaces the conventional stall warning vane on the left wing's leading edge and is the sensing element of the system (see Fig. 1). It contains a movable vane directly coupled to a pylon-mounted potentiometer. The vane senses and moves with the air flow pattern ahead of the wing, which varies directly with changes in wing angle of attack. The potentiometer translates the vane movement into a corresponding electrical signal. This electrical signal is then applied to the computer unit. The vane is free to rotate continuously through 360°.

2. Computer unit. The computer unit is made up of two sections of electronic circuitry. The angle-of-attack section contains a bridge circuit which transfers the vane signals into properly scaled voltages for the indicator unit. The stall-warning section contains an electronic switch which activates the existing red stall warning light. This unit is located on the floor aft of the pilot and below the baggage sub-floor (see Fig. 2).

3. Indicator unit. The angle-of-attack indicator unit is a DC 0 to 1 mA instrument mounted on the glare shield in front of the pilot. The scale is calibrated and color-coded to designate specific performance characteristics of Piper Cherokee 140 (see Fig. 3).

4. Stall warning light system. The stall-warning light system is the existing factory-installed equipment. The stall-warning light is located in the middle of the instrument panel in front of the pilot.

Of greatest concern to the pilot is the interpretation and use of the indicator unit. Figure 12 in Appendix B is a detailed diagram of the face of this display unit. Figure 4 is a close-up picture. The first thing to note is that the stall region or maximum angle-of-attack is at the left edge.

By proceding from left to right, or decreasing angle of attack, the markings on the display unit will be defined.

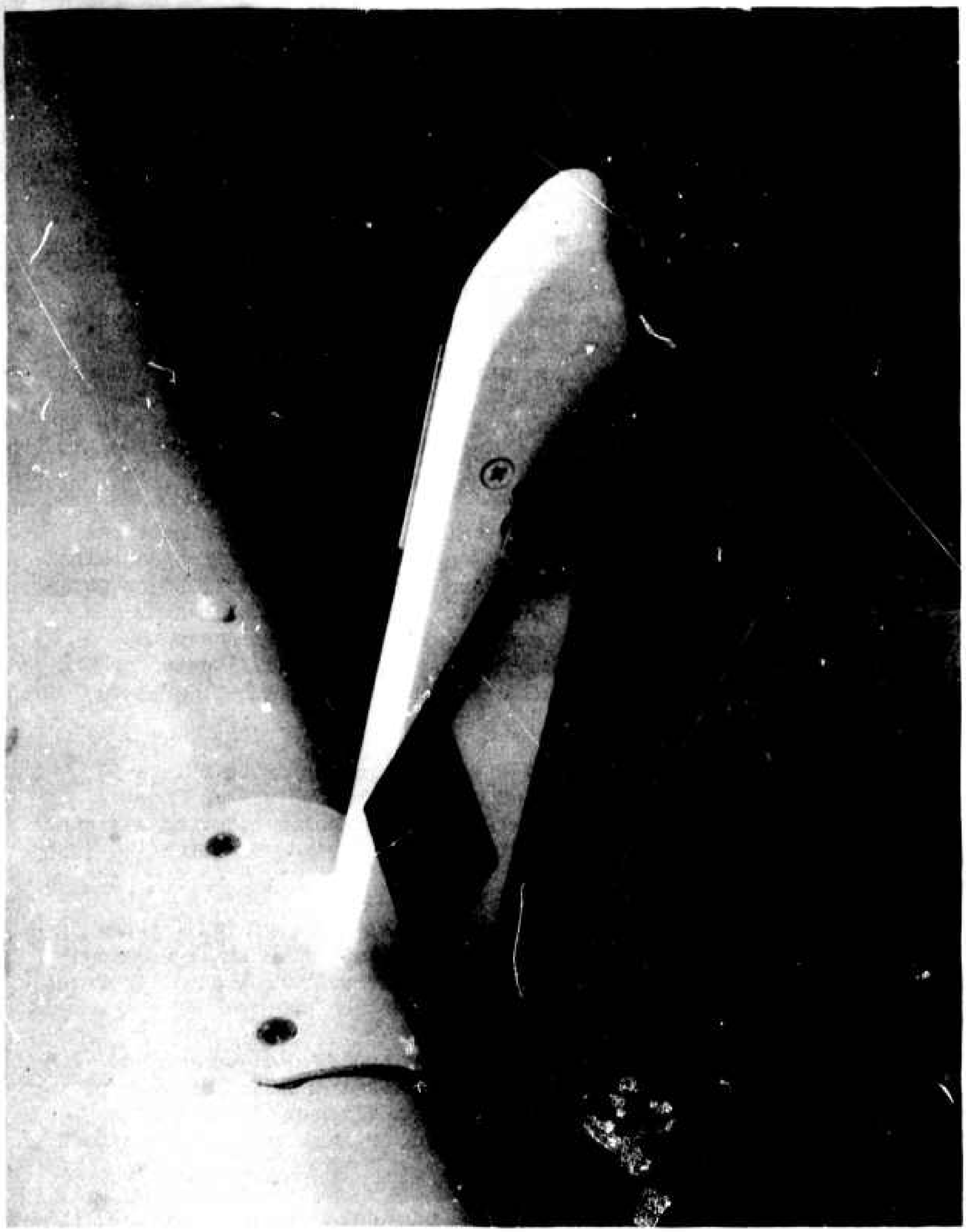


Fig. 1

Fig. 2

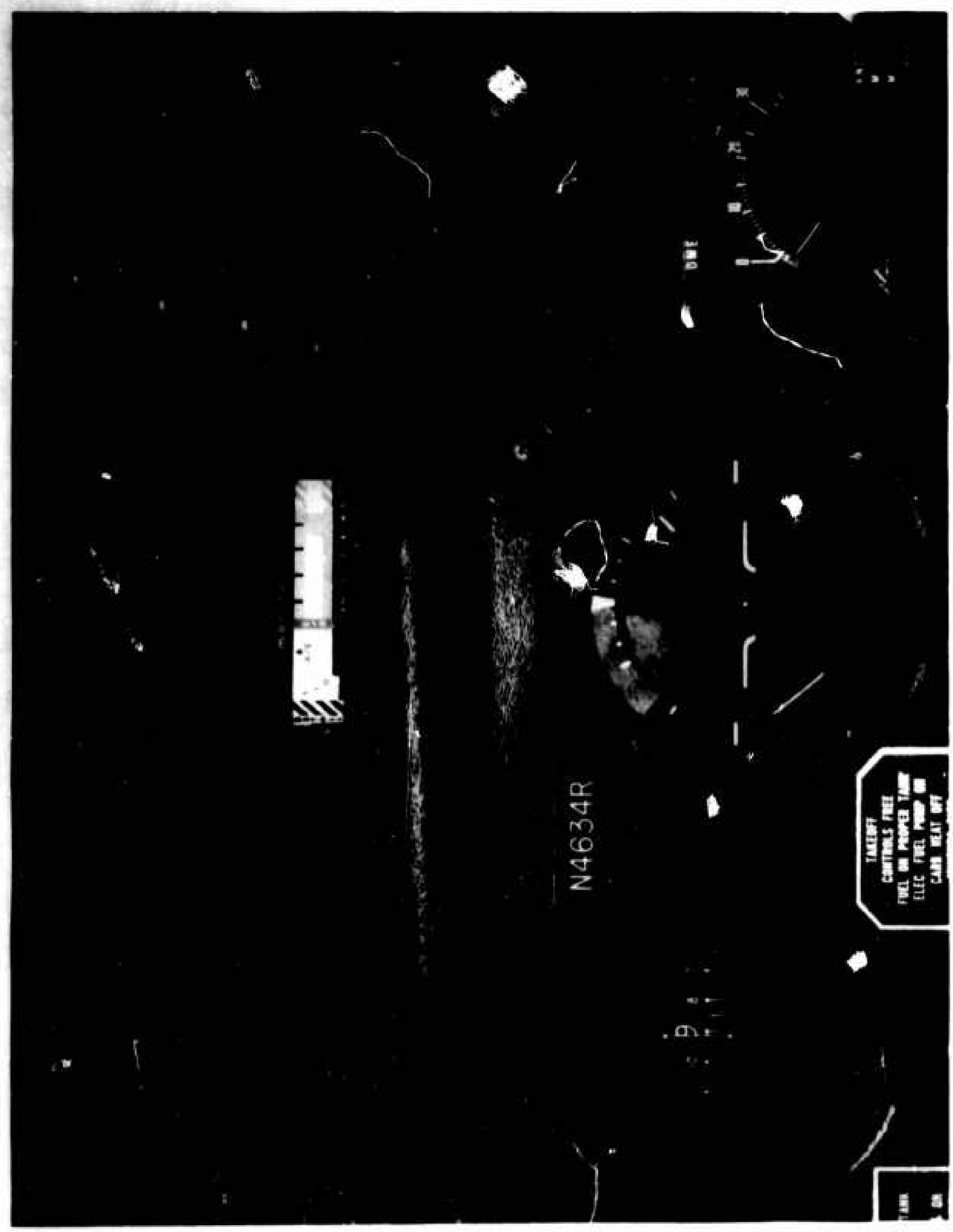

N4634R
TAKEOFF
CONTROLS FREE
FUEL ON PROPER TANK
ELEC FUEL PUMP ON
CARB HEAT OFF

Fig. 3

Fig. 4

The black and white "barber pole" region immediately to the right of the stall region is the <u>stall warning region</u>. When the angle of attack indicates in this region, the red stall-warning light should be on. The yellow SLO region merely indicates caution and will often be used for slow flight maneuvers.

The A/C index mark represents the angle of attack for maximum angle of climb.

The blue region with the letter C/D in the center corresponds to the proper angle-of-attack for best rate of climb and normal descents for landing.

The parallel green and white region immediately to the right of the blue bar can be used for slow cruise performance with the right edge of the center white bar corresponding to the maximum speed at which flaps can be operated.

The solid vertical green region indicates normal cruise performance at 65 per cent power. The width of this region is related to the variation in angle of attack that will arise for constant power setting as the aircraft's gross weight changes. The left edge of the solid green represents maximum gross weight, and the right edge corresponds to minimum gross weight.

The green and white "barber pole" region corresponds to airspeeds which exceed the rough air maneuvering speed of 129 mph. Thus, the left edge of this green and white region is not to be exceeded when maneuvering in rough air.

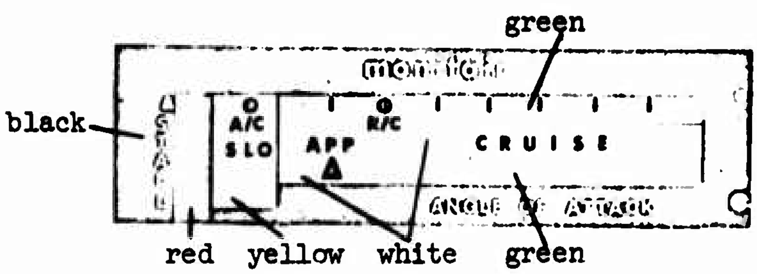
The above description refers to the Model 3010 instrumentation currently on the aircraft which was used during most of the winter academic quarter. The original instrumentation, Type 92-113, which was used throughout the Autumn Quarter is similar in principle of operation. Major differences, listed below, could be found in all components of the original system.

1. The sensor vane rotated through about 90°. The vane was coupled to the transmitter potentiometer through a series of mechanical linkages.

2. The computer unit, stall-warning section, produced a sharp light indication when the angle-of-attack display needle moved from right to left into the stall-warning section. However, there was a mechanical lag in going the other way; i.e., the stall-warning light stayed on as the needle moved through about 1/8 inch into the yellow region.

3. The original display units underwent two significant changes in scale markings and presentations, the third being the current

scale. The first two were similar; the second is shown schematically below.



The first one had indices which were used in the original certification for the Cherokee series; namely, for the Cherokee 235. Although Piper aircraft claimed no aerodynamic difference between the wings of the 235 and 140, it was found during flight calibrations at OSU that the marked indices would not correspond with airspeeds recommended for the Cherokee 140. Thus, the second dial, shown above, was installed. However, a draftsman's error at Monitair placed the A/C dot a half inch to the left. Throughout the Autumn Quarter, the best angle of climb was instead designated by the APP mark.

Prior to the initiation of this program at The Ohio State University, no set of instructional techniques existed for use with primary students. Considerable effort was expended in attempting to decide the instructional techniques and format for this experimental program. Within the month prior to the Autumn Quarter, repeated flights and checkouts of the instructors continued to bring to light new ideas as well as problems. When the Autumn Quarter started, many instructional difficulties remained. These problems will be fully discussed in the Discussion Section.

Pertinent to the description here and to the results described later is the sequence of initial instrumentation malfunctions. The most notable and serious was that sensor vanes were sluggish or sticking in cold damp weather. Monitair engineers diagnosed this problem as excessive friction in the transmitter potentiometers and made satisfactory repairs. Another problem, though relatively minor, was the display needle acting very erratic at certain power settings. This was attributed to aircraft vibrations being transmitted through the display mountings.

A completely new designed system, Model 3010, was installed in January, 1968, and used throughout the remainder of the Winter Quarter without difficulty and with complete reliability.

DISCUSSION

The results of this experimentation program have been derived from a composite of such sources as questionnaires, flight checks, and observer comments. Interpretation of the results are, in turn, sensitive to the experimental design and its administration. Both this experimental design and control were significantly changed midway through the program. Such normal experimental variables as instrumentation reliability and instructor standardization were the areas in which major changes were made. Consequently, it would be more meaningful to first discuss the results separately for each of the academic quarters, then if appropriate, to combine the students for both academic quarters in order to present an overall comparison.

STUDENT CHARACTERISTICS

The students that enrolled in the Autumn Quarter flight training program were, with one exception, all college students at the junior and senior class levels (see Tables I - IV). These students were considered to be extremely typical in background, age, and abilities for the type of student normally enrolled in the Aviation Department. There were originally three female students in the program. Two were dropped from the program because of extremely slow progress, and the third is still in training and hence not considered in the results.

All students were scheduled to fly one period a day, five days a week, for approximately 10 weeks. When weather did not permit flying, the student met with his instructor for a ground school type of session.

At the beginning of the Autumn quarter the angle-of-attack students were given a two hour orientation lecture on the concept of angle of attack and its use. Visual aids in the form of slides were used. The angle-of-attack group in the Winter group were given a similar orientation lecture but supplemented with a training manual.

It was the feeling of this writer who gave both lectures that the concept of angle of attack and its use were too abstract to be fully appreciated in one formal presentation. Since the students were just in the first week of flight training, there was an apparent lack of association with their brief experiences of aircraft attitude references and control. It was intended that the instructor in their daily relationship with the student would be able to make the strongest impact on the student's understanding of angle of attack.

As stated in the introduction, all students in the program were asked to take a battery of aptitude and personality tests. The results of these tests were analyzed for possible correlations with their flight

check scores. The correlation matrices are presented in Table VII. As can be seen, no significant correlations exist. The correlations involving the 16 Personality Factor Test, having 16 primary factors and 6 secondary factors, were not tabulated since no significant correlations were to be found.

An attempt was made to determine the ability of the flight instructor to evaluate the personality and aptitudes of his student. Answers from Instructor Questionnaire #2 were correlated to the aptitude and personality tests taken by the students. No significant correlations can be detected at this time.

FLIGHT INSTRUCTOR CHARACTERISTICS

The majority of the flight instructors in the Department of Aviation are college students (junior, senior, or graduate levels) working part-time as flight assistants for the Department's instructional staff. As can be seen from Tables V and VI, age and qualifications are to be considered average for this type of school. Supervision of the flight assistants rests with the chief flight instructor and the two full-time faculty flight instructors.

Orientation lectures were held with the flight instructors on the use and phraseology associated with teaching angle of attack. Specific instructions were given to avoid mentioning airspeed during the first week of flight training in order to "set" the students' thinking. Any temptation to use airspeed to verify a flight attitude was to be replaced with a reference to the angle-of-attack display. References to "fast" and "slow" were still to rely on angle of attack (e.g., to slow up; by increasing the angle of attack; i.e., by bringing the angle-of-attack needle to left with wheel back pressure and/or throttle reduction).

From the written critiques by the Autumn Quarter flight instructors (Appendix M) it appears that their orientation to the angle-of-attack system was inadequate and that some learned more about the device while teaching the student. It is also believed that there was considerable difficulty initially among the instructors to structure their instruction and phraseology about the angle-of-attack device. For example, an instructor would often refer to holding airspeed constant rather than angle of attack.

Instructor attitudes in the Autumn Quarter were seriously influenced by the unreliability of the angle-of-attack system which, in turn, was the result of mechanical problems discussed earlier. In summary, the instructor-student relationship in the Autumn quarter exposed quite clearly the difficulties in teaching and evaluating new instrumentation and concepts.

Table VII - Correlation Matrix

Aptitude Tests - Flight Performance

Control Group, N = 13

	Otis: Gamma	Owens Bennett	Flanagan	Stage I	Stage II	Final
Otis: Gamma	-	0.2018	0.3878	0.4987	0.3117	-0.1527
Owens - Bennett	0.2018	-	0.6176	-0.0382	0.1826	-0.2707
Flanagan (Test 15)	0.3878	0.6176	-	-0.1395	0.5667	-0.2460
Stage I Flt. Check	0.4987	-0.0382	-0.1395	-	-0.1579	-.0781
Stage II Flt. Check	0.3117	0.1826	0.5667	-0.1579	-	-0.0407
Final Flight Check	-0.1527	-0.2707	-0.2460	0.0781	-0.0407	-

Experimental Group, N = 15

	Otis: Gamma	Owens Bennett	Flanagan	Stage I	Stage II	Final
Otis: Gamma	-	0.3988	-0.0008	-0.3863	0.1138	0.1088
Owens - Bennett	0.3988	-	0.4950	-0.3685	0.0535	-0.1394
Flanagan (Test 15)	-0.0008	0.4950	-	-0.0250	0.0577	-0.0934
Stage I Flt. Check	-0.3863	-0.3685	-0.0250	-	-0.1290	-0.1896
Stage II Flt. Check	0.1138	0.0535	0.0577	-0.1290	-	0.1248
Final Flight Check	0.1088	-0.1394	-0.0934	-0.1896	0.1248	-

The experience gained by two of the instructors in the first quarter was used advantageously in the second quarter. However, the second quarter instructors had the advantage of a training manual and more frequent instructor meetings to clarify instructional problems. Also, the relative youth of this group of instructors tended to make them more adaptable and interested in the angle-of-attack system.

As in so many experiments in flight training, the instructor plays a key role. If he can be motivated and enthusiastic toward the program's objectives, the probabilities of assessing the true experimental effects increase considerably.

FLIGHT PERFORMANCE

The effectiveness of angle-of-attack instrumentation in student flight training should ultimately be determined by the student's relative flight performance. One of the first measures is the student's dual time to first solo.

The data for this measure are presented in Table VIII. It is quickly seen that no significant differences exist between the control and experimental groups, when considered by academic quarter or combined. Several explanations for this outcome are possible.

Much of the pre-solo training is devoted to landings and take-offs, where the greatest difficulty is not in the approach, but in the judgment and control of the flare and touchdown. The skills required for flare and touchdown do not in any way use the visual angle-of-attack display. It is therefore not surprising to find no difference between the groups. If a difference were to exist in favor of the angle of attack, it might have been explained as the result of a more intangible factor such as pilot confidence. That such a factor did not develop prior to solo allows for interesting speculation, and, as such, will not be discussed.

The other measures of student flight performance were the error scores on the Pilot Performance Description Records (PPDR) obtained on the Stage I, Stage II, and Final flight checks. It was hoped that through the PPDR the existance of performance differences would be detected.

The actual error scores by individual and by maneuver are presented in Tables IX to XIV. The data are summarized in two ways. For each group of students, the error score is averaged over all maneuvers for the flight check, resulting in an average flight check score for each student. This summary is shown in Table XV. The second way is to consider the error score for each maneuver averaged over all students in the group. These scores are summarized in Tables XVI - XVIII.

Table VIII

Flight Time To First Solo

CA		EA	
C1	8.4	E1	6.5
C2	10.9	E2	8.2
C3	9.5	E3	11.2
C4	11.4	E4	10.8
C5	9.0	E5	12.0
C6	8.8	E6	7.2
C7	7.6	E7	14.9
C8	14.4	E8	12.5
Mean	10.0	Mean	10.41
S.D.	2.17	S.D.	2.88

CW		EW	
C9	11.7	E9	6.5
C10	10.5	E10	12.6
C11	11.2	E11	11.6
C12	15.5	E12	13.9
C13	10.2	E13	14.7
C14	10.3	E14	--
C15	9.5	E15	12.7
C16	11.7	E16	10.9
C17	10.4	E17	8.8
C18	10.3	Mean	11.46
Mean	11.13	S.D.	2.68
S.D.	1.68		
Combined Mean	10.63	Combined Mean	10.94
Combined S.D.	1.93	Combined S.D.	2.75

Table IX

Stage I - Flight Check Error Scores
(Autumn Quarter)

			Preflight, taxi & run-up	Takeoff and climbout	Level flight	Slow flight - Into and Maintaining	Slow flight- Out of	Departure Stall	Approach Stall	Emergency Procedures	Downwind Leg	Base Leg	On Final	Flare, touch down roll out
CA	C1		00	05	03	05	03	04	09	03	03	01	04	01
	C2		07	10	02	02	03	06	07	00	05	04	12	03
	C3		00	06	03	03	02	06	01	08	01	05	04	00
	C4		04	12	09	11	03	08	18	07	07	17	06	01
	C5		00	07	02	04	02	06	05	06	04	01	02	02
	C6		00	06	02	06	01	05	09	08	04	03	06	15
	C7		00	03	04	05	05	10	10	03	06	02	03	07
	C8		01	05	04	07	01	09	09	07	04	01	01	02
		Mean	1.50	6.75	3.63	5.38	2.50	6.75	8.50	5.25	4.25	4.25	4.75	3.88
		S.D.	2.62	2.92	2.33	2.77	1.31	2.05	4.84	2.92	1.83	5.37	3.41	4.97
EA	E1		00	12	01	02	01	01	06	00	03	00	01	01
	E2		00	07	00	03	01	13	07	05	04	17	16	15
	E3		02	07	04	03	04	06	04	08	03	17	10	08
	E4		01	03	02	02	03	04	09	10	04	04	07	01
	E5		01	03	05	04	02	06	06	09	01	02	09	07
	E6		04	03	03	04	03	05	04	06	03	05	01	03
	E7		01	10	05	04	03	17	12	06	03	07	11	04
	E8		00	03	00	05	03	09	13	06	08	10	05	04
		Mean	1.13	6.00	2.50	3.38	2.50	7.63	7.63	6.25	3.63	7.75	7.50	5.38
		S.D.	1.36	3.59	2.07	1.06	1.07	5.16	3.42	3.06	2.00	6.45	5.13	4.63

Table X

Stage I - Flight Check Error Scores
(Winter Quarter)

			Preflight, taxi & run-up	Takeoff and climbout	Level flight	Slow flight - Into and Maintaining	Slow flight - Out of	Departure Stall	Approach Stall	Emergency Procedures	Downwind Leg	Base Leg	On Final	Flare, touch down roll out
CW	C9		00	03	03	04	01	03	01	06	04	00	00	01
	C10		01	11	02	05	03	11	13	11	08	05	06	07
	C11		00	00	00	03	02	03	02	00	02	02	00	05
	C12		01	13	08	05	03	10	11	06	06	08	03	05
	C13		02	07	02	06	03	06	07	06	08	05	06	06
	C14		00	04	02	05	04	07	12	06	02	03	00	05
	C15		00	09	02	06	03	08	04	03	05	01	00	00
	C16		00	01	01	03	02	15	14	06	05	10	08	01
	C17		02	01	01	05	06	10	09	07	06	04	03	04
	C18		04	07	02	02	02	07	08	12	04	01	02	07
		Mean	1.00	5.60	2.30	4.40	2.90	8.50	8.10	6.30	5.00	3.90	2.80	4.10
		S.D.	1.33	4.50	2.16	1.35	1.37	3.68	4.58	3.43	2.11	3.21	2.97	2.56
EW	E9		00	12	04	06	04	00	10	07	05	05	07	03
	E10		02	04	01	01	05	08	05	03	03	03	05	06
	E11		00	04	02	02	01	02	00	06	03	04	04	02
	E12		00	01	04	02	03	11	14	01	02	08	06	04
	E13		01	05	02	03	04	10	05	02	03	02	01	08
	E14		02	04	03	02	05	12	13	01	02	04	03	03
	E15		00	03	04	02	07	17	12	10	05	03	01	03
	E16		00	05	02	04	07	09	02	09	03	01	08	05
	E17		03	01	02	04	00	04	02	09	05	05	00	01
		Mean	.89	4.33	2.67	2.89	4.00	8.11	7.00	5.33	3.44	3.89	3.89	3.89
		S.D.	1.17	3.24	1.12	1.54	2.40	5.33	5.32	3.64	1.24	2.03	2.85	2.15

Table XI

Stage II - Flight Check Error Scores
(Autumn Quarter)

			Preflight, taxi, run-up	Takeoff and climbout	Level flight	Slow flight - Into & Maintaining	Slow flight - Out of	Departure Stall*	Approach Stall	Emergency Procedures	Downwind Leg	Base Leg	On Final	Flare, T.D. & roll out
CA	C1		00	13	01	04	04	--	06	00	03	01	05	03
	C2		00	03	03	05	01	--	04	03	03	01	06	06
	C3		00	01	00	00	01	--	04	02	02	01	00	00
	C5		05	03	00	03	01	--	03	03	04	04	10	04
	C7		00	04	02	03	02	--	04	02	05	02	05	01
	C8		01	01	01	01	02	--	02	03	05	02	03	00
		Mean	1.00	4.17	1.17	2.67	1.83	----	3.83	2.17	3.67	1.83	4.83	2.33
		S.D.	2.00	4.49	1.17	1.86	1.17	----	1.32	1.17	1.21	1.17	3.31	2.42
EA	E1		02	14	02	04	03	--	10	02	04	06	07	04
	E2		02	06	03	04	02	--	05	04	01	01	03	03
	E3		01	09	01	03	02	--	05	04	03	08	04	05
	E6		00	09	03	02	04	--	05	02	03	02	03	06
	E7		00	08	01	06	03	--	09	09	02	04	07	07
		Mean	1.00	9.20	2.00	3.80	2.80	----	6.80	4.20	2.60	4.20	4.80	5.00
		S.D.	1.00	2.95	1.00	1.48	.84	----	2.49	2.86	1.14	2.86	2.05	1.58

*The Pilot Performance Description Records used in this academic quarter did not include the departure stall in the Stage II flight check.

Table XII

Stage II - Flight Check Error Scores
(Winter Quarter)

			Preflight, taxi, run-up	Takeoff and climbout	Level flight	Slow slight - Into & Maintaining	Slow flight - Out of	Departure Stall	Approach Stall	Emergency Procedures	Downwind Leg	Base Leg	On Final	Flare, T.D. & roll out
CW	C10		03	00	01	03	02	04	05	00	04	06	00	06
	C11		02	00	00	03	03	05	07	03	03	04	02	05
	C14		00	00	01	03	01	04	06	00	06	01	00	00
	C15		00	03	01	02	01	06	07	07	04	04	02	00
	C16		00	00	00	03	01	05	08	06	04	00	01	02
	C17		00	02	01	05	02	04	06	05	02	03	05	04
	C18		02	01	00	01	06	05	10	01	00	07	03	04
		Mean	1.00	.86	.57	2.86	2.29	4.71	7.00	3.14	3.29	3.57	1.86	3.00
		S.D.	1.29	1.22	.53	1.22	1.80	.76	1.63	2.91	1.89	2.51	1.77	2.38
EW	E9		00	02	00	00	00	03	06	00	03	03	05	03
	E10		00	10	01	03	02	05	04	09	04	02	03	00
	E11		00	05	01	02	00	03	08	08	01	00	00	01
	E12		00	01	02	06	01	08	03	03	01	03	05	06
	E13		00	05	01	02	01	01	03	10	06	05	04	00
	E15		00	00	00	03	02	00	09	08	05	04	08	07
	E16		00	00	03	02	03	09	13	03	03	04	07	08
	E20		00	02	04	05	04	07	14	01	04	01	05	00
		Mean	0	3.12	1.50	2.88	1.63	4.50	7.50	5.25	3.38	2.75	4.63	3.13
		S.D.	0	3.40	1.41	1.89	1.41	3.30	4.31	3.92	1.77	1.67	2.45	3.40

Table XIII

Final Flight Check Error Scores
(Autumn Quarter)

			Takeoff and climbout	Slow flight - Into & Maintaining	Slow flight - Out of	Departure Stall	Approach Stall	Acceleration Stall	Emergency Procedures	Downwind leg - Normal landing	Base leg - Normal landing	On Final - Normal landing	Flare, T.D., rollout - Normal landing
CA	C1		01	01	03	02	01	01	02	03	03	01	01
	C2		04	06	03	02	06	08	00	03	06	02	01
	C4		02	00	00	04	06	03	00	03	06	00	04
	C5		03	03	02	04	03	06	06	02	00	05	02
	C6		08	03	02	05	03	01	02	00	01	04	03
	C7		02	04	03	04	04	08	00	04	03	04	02
	C8		04	02	02	05	00	04	02	04	01	01	00
		Mean	3.43	2.71	2.14	3.71	3.29	4.43	1.71	2.71	2.86	2.43	1.86
		S.D.	2.30	1.98	1.07	1.25	2.29	2.99	2.14	1.38	2.41	1.90	1.35
EA	E1		00	02	01	01	02	03	00	02	00	02	00
	E2		05	01	02	02	00	04	01	00	02	03	01
	E3		06	04	02	02	02	05	04	02	06	02	04
	E4		04	01	01	03	01	01	07	01	01	01	01
	E5		07	04	02	04	00	00	03	01	03	01	03
	E6		02	05	02	08	02	06	03	03	08	07	10
	E7		06	02	05	02	03	02	03	02	02	04	03
	E8		01	04	00	01	03	00	03	02	03	03	03
		Mean	3.88	2.88	1.88	2.88	1.63	2.63	3.00	1.63	3.13	2.87	3.13
		S.D.	2.59	1.55	1.46	2.30	1.19	2.26	2.07	.92	2.64	1.96	3.09

Table XIV

Final Flight Check Error Scores (Winter Quarter)

		Takeoff and climbout	Slow flight - Into & Maintaining	Slow flight - Out of	Departure Stall	Approach Stall	Acceleration Stall	Steep turns	Emergency Procedures	Downwind leg - Normal landing	Base leg - Normal landing	On Final - Normal landing	Flare, T.D., rollout - Normal landing	Downwind leg - Short field landing	Base leg - Short field landing	On Final - Short field landing	Flare, T.D. & rollout - Short field landing
CW	C9	06	01	06	04	05	05	06	06	04	07	04	06	04	05	00	00
	C10	06	01	06	04	04	03	05	03	03	01	04	02	03	03	05	04
	C11	03	02	02	04	03	01	07	06	03	00	03	00	03	02	02	03
	C12	01	02	01	03	05	04	00	04	03	01	03	04	01	01	02	04
	C13	03	03	01	07	08	04	09	03	02	00	01	00	05	01	04	04
	C14	02	03	02	08	02	01	00	03	02	03	06	00	02	01	03	06
	C15	02	00	01	05	03	06	01	03	04	01	00	05	03	01	03	05
	C16	04	04	01	01	01	05	03	01	02	01	04	00	03	02	03	04
	C17	01	01	03	02	04	05	00	03	04	00	00	00	02	03	01	04
	C18	02	02	03	02	00	00	02	00	02	01	01	09	02	00	00	01
	Mean	3.00	1.90	2.60	4.00	3.50	3.40	3.30	3.20	2.90	1.50	2.60	2.60	2.80	1.90	2.30	3.50
	S.D.	1.83	1.20	1.96	2.21	2.27	2.07	3.27	1.87	.88	2.12	2.01	3.24	1.14	1.45	1.64	1.78
EW	E9	10	03	02	02	00	00	00	00	03	01	01	04	00	00	01	03
	E10	06	02	01	01	08	00	05	04	02	01	02	02	02	01	03	05
	E11	05	04	02	04	00	06	05	00	00	02	05	01	04	00	00	07
	E12	03	01	01	03	07	01	02	00	02	02	02	02	00	00	00	01
	E13	03	02	02	02	01	03	05	08	03	01	02	03	02	01	02	02
	E14	02	01	05	03	03	03	05	03	01	01	01	01	03	02	00	00
	E15	09	02	02	02	01	01	05	00	01	01	01	01	01	01	04	01
	E16	05	02	01	01	01	08	13	03	00	00	00	02	02	01	01	04
	E17	08	03	02	02	01	04	01	00	02	04	04	03	03	00	02	08
	Mean	5.67	2.22	2.00	2.22	2.44	2.89	4.56	2.00	1.56	1.44	2.00	2.11	1.89	.67	1.44	3.44
	S.D.	2.82	.97	1.22	1.00	3.01	2.75	3.75	2.78	1.13	1.13	1.58	1.05	1.16	.71	1.42	2.79

Table XV

Summary - Student Flight Performance
(Average Error Score)

	Stage I	Stage II	Final
Control Group, Autumn Quarter (CA)			
C1	3.42	3.64	1.50
C2	5.08	3.18	3.31
C3	3.25	0.92	--
C4	8.60	--	2.69
C5	3.42	3.75	2.69
C6	5.42	--	3.91
C7	4.83	2.46	3.38
C8	4.25	1.91	2.30
Mean	4.78	2.64	2.83
S.D.	1.73	1.10	0.79
Experimental Group, Autumn Quarter (EA)			
E1	2.34	5.27	1.42
E2	7.35	1.93	2.46
E3	6.33	3.88	3.88
E4	4.16	--	1.80
E5	4.16	--	3.36
E6	3.67	3.53	5.08
E7	6.92	5.09	2.63
E8	5.50	--	1.33
Mean	5.16	3.94	2.71
S.D.	1.71	1.35	1.27
Group Difference	-0.38	-1.30	0.12
t value	-0.500	-1.728	.187
d.f.	16	9	13
Significance Level	--	.10	--

Table XV - Continued

	Stage I	Stage II	Final	Final*
Control Group, Winter Quarter (CW)				
C9	2.16	--		4.32
C10	6.92	3.38		3.56
C11	1.58	2.28		2.77
C12	6.58	--		2.44
C13	5.33	--		3.44
C14	4.16	1.85		2.75
C15	2.75	2.70		2.68
C16	5.50	2.08		2.38
C17	4.83	3.45		2.06
C18	4.83	2.30		1.69
Mean	4.46	2.58		2.81
S.D.	1.80	0.62		0.77
Experimental Group, Winter Quarter (EW)				
E9	5.45	2.25	2.36	1.63
E10	3.84	7.20	2.93	3.60
E11	2.50	1.80	2.84	3.20
E12	4.66	2.60	2.08	2.82
E13	3.84	2.60	2.55	1.55
E14	4.50	--	2.09	2.00
E15	5.59	4.00	2.06	1.88
E16	4.68	3.55	3.00	3.00
E17	3.00	3.18	2.58	2.14
Mean	4.23	3.40	2.42	2.50
S.D.	1.03	1.69	0.74	0.37

* The final flight test for this experimental group was repeated but without the use of the angle of attack system.

	Stage I	Stage II	Final	Final*
Group Difference	0.23	- .82	.39	.31
t value	.347	-1.277	1.021	1.140
d.f.	16	9	19	15
Significance Level	.40	.20	.20	.20

Table XVI

Summary - Stage I Flight Check
(Average Error Score)

	CA	EA	Diff.	CW	EW	Diff.	C	E	Diff.
Preflight, taxi & run-up	1.50	1.13	0.37	1.00	0.89	0.11	1.22	1.00	0.22
Takeoff and climbout	6.75	6.00	0.75	5.60	4.33	1.27	6.11	5.12	0.99
Level flight	3.63	2.50	0.13	2.30	2.67	-0.37	2.89	2.59	0.30
Slow flight - Into and Maintaining	5.38	3.38	2.00	4.40	2.89	1.51	4.83	3.12	1.71
Slow flight - Out of	2.50	2.50	0	2.90	4.00	-1.10	2.72	3.29	-0.57
Departure Stall	6.75	7.63	-0.88	8.00	8.11	-0.11	7.44	7.88	-0.44
Approach Stall	8.50	7.63	0.87	8.10	7.00	1.10	8.28	7.29	0.99
Emergency Procedure	5.25	6.25	-1.00	6.30	5.33	0.97	5.83	5.77	0.06
Downwind Leg	4.25	3.63	0.66	5.00	3.44	1.56	4.67	3.53	1.14
Base Leg	4.25	7.75	-3.50	3.90	3.89	0.01	4.06	5.71	-1.65
On Final	4.75	7.50	-2.75	2.80	3.89	-1.09	3.67	5.59	-1.92
Flare, touch down, roll out	3.88	5.38	-1.50	4.10	3.89	0.21	4.00	4.59	-0.59
N	8	8		10	9		18	17	

Table XVII

Summary - Stage II Flight Check
(Average Error Score)

	CA	EA	Diff.	CW	EW	Diff.	C	E	Diff.
Preflight, taxi, run-up	1.00	1.00	0	1.00	0	1.00	1.00	0.38	0.62
Takeoff and climbout	4.17	9.20	-5.03	0.86	3.12	-2.26	2.38	5.46	-3.08
Level flight	1.17	2.00	-0.83	0.57	1.50	-0.93	0.85	1.69	-0.84
Slow flight - Into & Maintaining	2.67	3.80	-1.13	2.86	2.87	-0.01	2.77	3.23	-0.46
Slow flight - Out of	1.83	2.80	-0.97	2.29	1.62	0.67	2.07	2.07	0
Departure Stall	-	-	-	4.71	4.50	0.21	-	-	-
Approach Stall	3.83	6.00	-2.97	7.00	7.50	-0.50	5.54	7.23	-1.69
Emergency Procedures	2.17	4.20	-2.03	3.14	5.25	-2.11	2.69	4.85	-2.16
Downwind Leg	3.67	2.60	1.07	3.29	3.37	-0.08	3.46	3.08	0.38
Base Leg	1.83	4.20	-2.37	3.57	2.75	0.82	2.77	3.31	-0.54
On Final	4.83	4.80	0.03	1.86	4.62	-2.76	3.23	4.69	-1.46
Flare, T.D. & roll out	2.33	5.00	-2.67	3.00	3.12	-0.12	2.69	3.85	-1.16
N	6	5		7	8		13	13	

Table XVIII

Summary - Final Flight Check
(Average Error Score)

	CA	EA	Diff.	CW	EW	Diff.	C	E	Diff.
Takeoff and climbout	3.43	3.88	-0.45	3.00	5.67	-2.67	3.18	4.82	-1.64
Slow flight - Into & Maintaining	2.71	2.88	-0.17	1.90	2.22	-0.32	2.24	2.53	-0.29
Slow flight - Out of	2.14	1.88	0.26	2.60	2.00	0.60	2.41	1.94	0.47
Departure Stall	3.71	2.88	0.83	4.00	2.22	1.78	3.88	2.53	1.35
Approach Stall	3.29	1.63	1.66	3.50	2.44	1.06	3.41	2.05	1.36
Acceleration Stall	4.43	2.63	1.80	3.40	2.89	0.51	3.82	2.76	1.06
Steep turns	-	-	-	3.30	4.56	-1.26	-	-	-
Emergency Procedures	1.71	3.00	-1.29	3.20	2.00	1.20	2.59	2.47	0.12
Downwind leg - Normal landing	2.71	1.63	1.08	2.90	1.56	1.34	2.82	1.59	1.23
Bare leg - Normal landing	2.86	3.13	-0.27	1.50	1.44	0.06	2.06	2.33	-0.27
On Final - Normal landing	2.43	2.88	-0.45	2.60	2.00	0.60	2.53	2.41	0.12
Flare, T.D., roll out - Normal landing	1.86	3.12	-1.26	2.60	2.11	0.49	2.29	2.58	-0.29
Downwind leg - Short field landing	-	-	-	2.80	1.89	0.91	-	-	-
Bare leg - Short field landing	-	-	-	1.90	0.67	1.23	-	-	-
On Final - Short field landing	-	-	-	2.30	1.44	0.86	-	-	-
Flare, T.D. & roll out - Short field landing	-	-	-	3.50	3.44	0.06	-	-	-
N	7	8		10	9		17	17	

To determine whether these error scores indicate significant differences, it is necessary to also compute the variability of scores within the group; i.e., the sample variance or the standard deviation (SD).

From the summary of student flight performance presented in Table XV, which lists the average error score for overall performance for each of the student's flight checks, it can be said that there is no significant difference between the control and experimental groups for the Stage I and Final flight checks. The Stage II check, however, shows a slight difference in favor of the control groups.

The Stage II results also affect the expected trend of lower error scores on succeeding flight checks. The experimental groups show a uniform trend of lower error scores, but the control groups reach their lowest error score at the Stage II check with little change on the Final check. This would imply a faster learning rate for the control groups, or some disturbance in the learning rate in the experimental groups. One possible such disturbance may be the introduction of the airspeed instrument which occurs just prior to the Stage II check and in preparation for the cross-country phase.

Another observation from Table XV is the final flight check performance of the Winter quarter experimental group, EW. The students flew two final checks: the first was with the angle of attack, the second without. The airspeed instrument was available for both flight checks. Mean error scores for both checks show no difference in performance.

The fact that the second flight check was always without the angle-of-attack system and always immediately following the first flight check (i.e., examiner and student did not leave the airplane, but merely repeated selected maneuvers) introduced a possible bias in the results. The final check flights should have been randomized with respect to ordering the use of angle of attack.

When one considers that the angle-of-attack information is more applicable to such maneuvers as landings, takeoffs, slow flight, and stall, it is appropriate to present the error scores by maneuver. Thus, Tables XVI - XVIII, which summarize the average error scores for each maneuver, allows for a more detailed evaluation of the angle-of-attach system.

A statistical analysis was first used on the combined control groups, C = CA + CW, versus the combined experimental groups, E = EA + EW, and then applied separately for each quarter (i.e., CA vs EA and CW vs EW). This analysis computed, for each maneuver, the difference in mean error scores between the two groups and their associated variances. A modified t statistic was then computed.* By considering

*It was necessary to use the modified t statistic because of unequal sample sizes and unequal sample variances. See Appendix F for further details and formulas.

the degrees of freedom with each t value, it is possible to determine the probability of occurrence for that value of t. If t is large and the probability value of occurrence is small, then one concludes that the difference between the control and experimental groups is significant and is not the result of random variation.

Table XIX presents, for each flight check, the ranking of those maneuvers having significant t values. It should be noted that where there is no statistical significance, the ranking of the maneuvers would be quite meaningless. Furthermore, it is advisable where apparent contradictions occur that the basic error scores (Tables IX-XIV) should be reviewed to see if one or two students with very bad performances could have contributed to the significant t values. The t statistic and test normally used with small samples can be very sensitive to one or two bad scores.

Table XIX suggests a number of preliminary conclusions at the Stage I level; angle-of-attack students do better at entering and maintaining slow flight. The control group does better in a number of different maneuvers, in particular, in the base leg. Why the angle-of-attack students do worse on these maneuvers raises some difficult questions regarding their ability or the instructional techniques used in getting the student and aircraft "set up" for the approach. It wasn't until Winter Quarter that the procedure was required whereby the angle-of-attack approaches should be all set up on the base leg and that major control changes should be occurring on late downwind or very early base leg.

The Stage II check flight scores are almost unanimous in favor of the control students. As previously discussed, the Stage II check flight for an angle-of-attack student occurs at the time the student is preparing to go cross country and when the instructor has already introduced the use of the airspeed instrument. The use of the airspeed and the angle-of-attack instruments together may have produced some difficulty. If the emphasis by the instructor is now on airspeed, it is possible that adapting to airspeed control may be the cause for the poor performance at this particular stage of the flight training program. It is interesting to note that all the significant maneuvers in the Stage II check are maneuvers in the traditional training syllabus which strongly depend on airspeed control.

By the end of the training program, the angle-of-attack students appear to dominate the significant maneuvers and where these maneuvers are each intuitively easier to justify. The only two contradictions are the emergency maneuvers in Autumn Quarter and the climbout maneuver in Winter Quarter.

Table XIX-A

Significant Flight Maneuvers - Autumn Quarter

Maneuver	Mean Error Difference (CA-EA)	t value	d.f.	Significance Level
Stage I Check Flight				
Slow flight - Into and Maintaining	2.000	1.9046	10	.05
Final Approach	-2.750	-1.2630	14	.15
Base Leg	-3.500	-1.1796	15	.15
Stage II Check Flight				
Approach Stall	-2.9667	-2.3949	7	.025
Take-off and Climbout	-5.0333	-2.2286	10	.025
Flare, T.D. and roll out	-2.6667	-2.1936	10	.05
Base Leg	-2.3667	-1.7317	6	.10
Slow Flight - Out Of	-0.9667	-1.5940	11	.10
Downwind Leg	1.0667	1.5018	11	.10
Emergency	-2.0333	-1.4878	6	.10
Final Check Flight				
Downwind Leg	1.0893	1.7740	12	.10
Approach Stall	1.6607	1.7271	10	.10
Acceleration Stall	1.8036	1.3018	13	.10
Emergency	-1.2857	-1.1792	15	.15

Table XIX-B

Significant Flight Maneuvers - Winter Quarter

Maneuver	Mean Error Difference (CW-EW)	t value	d.f.	Significance Level
Stage I Check Flight				
Slow Flight - Into and Maintaining	1.5111	2.2664	18	.025
Downwind Leg	1.5556	1.9849	16	.05
Slow Flight - Out Of	-1.1000	-1.2098	14	.15
Stage II Check Flight				
Final Approach	-2.7679	-2.5301	14	.025
Take-off and Climbout	-2.2679	-1.7628	10	.10
Emergency	-2.1071	-1.1909	15	.15
Final Check Flight				
Downwind Leg	1.3444	2.8753	17	.005
Take-off & Climbout	-2.6667	-2.4121	15	.025
Base Leg - Short field	1.2333	2.3933	14	.025
Departure Stall	1.7778	2.3070	13	.025
Downwind Leg - Short field	0.9111	1.5726	17	.10
Final Approach - Short field	0.8556	1.2184	19	.15

Table XIX-C

Significant Flight Maneuver - Overall Comparison

Maneuver	Mean Error Difference (C-E)	t value	d.f.	Significance Level
Stage I Check Flight				
Slow Flight - Into and Maintaining	1.7157	2.9187	30	.005
Downwind Leg	1.1373	1.8860	34	.05
Final Approach	-1.9216	-1.4739	31	.10
Base Leg	-1.6503	-1.0678	33	.15
Stage II Check Flight				
Take-off & Climbout	-3.0769	-1.9864	25	.05
Emergency	-2.1538	-1.8814	22	.05
Approach Stall	-1.6923	-1.4465	21	.10
Final Approach	-1.4615	-1.4383	24	.10
Final Check Flight				
Downwind Leg	1.2353	3.4641	34	.005
Departure Stall	1.3529	2.2313	34	.025
Take-off & Climbout	-1.6471	-1.9867	30	.05
Approach Stall	1.0588	1.2553	34	.15

Table XX

Summary - Student Performance: Control Group - Autumn Quarter

Student	C1	C2	C3	C4	C5	C6	C7	C8
Time To Solo	8.4	10.9	9.5	11.4	9.0	8.8	7.6	14.4
Flight Check Error Score								
Stage I	3.42	5.08	3.25	8.60	3.42	5.42	4.83	4.25
Stage II	3.64	3.18	0.92	--	3.75	--	2.46	1.91
Final	1.50	3.31	--	2.69	2.69	3.91	3.38	2.30
Instructor's Opinion Of Rate Of Progress								
At First	Fast	Fast	Fast	Slow	Slow	Slow	Fast	Average
Pre-Solo Phase	Fast	Average	Fast	Average	Average	Average	Fast	Average
Solo Phase	Fast	Average	Fast	Average	Fast	Fast	Fast	Average
Cross-Country-Phase	Fast	Average	Fast	Fast	Average	Fast	Fast	Average
Final Preparation	Average	Fast	Average	Average	Average	Average	Average	Average
FAA Written Exam	95	76	85	70	80	--	77	92
Flight Instructor	I10	I1	I8	I2	I7	I6	I9	I9

Table XXI

Summary - Student Performance: Experimental Group - Autumn Quarter

Student	E1	E2	E3	E4	E5	E6	E7	E8
Time To Solo	6.5	8.2	11.2	10.8	12.0	7.2	14.9	12.5
Flight Check Error Scores								
Stage I	2.34	7.33	6.33	4.16	4.16	3.67	6.92	5.50
Stage II	5.27	1.93	3.88	--	--	3.53	5.09	--
Final	1.42	2.46	3.88	1.80	3.36	5.08	2.63	1.33
Instructor's Opinion Of Rate Of Progress								
At First	Fast	Slow	Average	Average	Slow	Fast	Average	Fast
Pre-Solo Phase	Fast	Average	Fast	Average	Slow	Fast	Slow	Average
Solo Phase	Fast	Average	Average	Fast	Slow	Fast	Average	Fast
Cross-Country-Phase	Average	Average	Average	Fast	Average	Fast	Average	Fast
Final Preparation	Average	Average	Average	Average	Average	Fast	Average	Average
FAA Written Exam	85	75	70	90	--	78*	--	82
Flight Instructor	I5	I16	I1	I2	I1	I7	I9	I11

* Took test twice; failed first

Table XXII

Summary - Student Performance: Control Group - Winter Quarter

Student	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
Time To Solo	11.7	10.5	11.2	15.5	10.2	10.3	9.5	11.7	10.4	10.3
Flight Check Error Scores										
Stage I	2.16	6.92	1.58	6.58	5.33	4.16	2.75	5.50	4.83	4.83
Stage II	--	3.38	2.28	--	--	1.85	2.70	2.08	3.45	2.30
Final	4.32	3.56	2.77	2.44	3.44	2.75	2.68	2.38	2.06	1.69
Instructor's Opinion Of Rate Of Progress										
At First	Slow	Slow	Average	Slow	Average	Fast	Average	Slow	Average	Slow
Pre-Solo Phase	Slow	Slow	Average	Slow	Average	Average	Average	Slow	Slow	Slow
Solo Phase	Slow	Slow	Fast	Fast	Fast	Fast	Average	Average	Average	Average
Cross-Country-Phase	Slow	Slow	Fast	Average	Fast	Fast	Average	Average	Fast	Average
Final Preparation	Slow	Slow	Fast	Average	Fast	Fast	Average	Average	Fast	Fast
FAA Written Exam	70	--	98	93	75*	83	69	83	85	75
Flight Instructor	I13	I15	I2	I14	I16	I1	I1	I13	I12	I12

* Took test twice; failed first

Table XXIII

Summary - Student Performance: Experimental Group - Winter Quarter

Student	E9	E10	E11	E12	E13	E14	E15	E16	E17
Time To Solo	6.5	12.6	11.6	13.9	14.7	17.1	12.7	10.9	8.8
Flight Check Error Score									
Stage I	5.45	3.84	2.50	4.66	3.84	4.50	5.59	4.66	3.00
Stage II	2.25	7.20	1.80	2.60	2.60	--	4.00	3.55	3.18
Final	4.63	3.60	3.20	2.82	1.55	2.00	1.88	3.00	2.14
Instructor's Opinion Of Rate Of Progress									
At First	Slow	Slow	Average	Fast	Fast	Fast	Average	Fast	Fast
Pre-Solo Phase	Fast	Slow	Average	Average	Average	Slow	Average	Fast	Fast
Solo Phase	Average	Fast	Fast	Average	Average	Slow	Slow	Slow	Fast
Cross-Country-Phase	Fast	Average	Fast	Fast	Fast	Average	Average	Average	Fast
Final Preparation	Fast	Average	Fast	Fast	Fast	Average	Slow	Average	Fast
FAA Written Exam	90	78	95	78	95	75*	90*	75	88
Flight Instructor	I1	I14	I2	I15	I15	I16	I13	I2	I12

* Took test twice; failed first

As can be seen from Tables XX - XXIII, the sample of control and experimental students are fairly typical as to ability; some are good and some are poor. Because of the inherently wide variability in student characteristics and abilities, it is firmly believed that the number of students in both groups was too small for the sensitivity now desired in an experimentation program of this type.

Observations were requested from the school's Chief Flight Instructor, and to FAA Designated Examiner. The Principal Operations Inspector from the local FAA General Aviations District Office "spot checked" one of the experimental students. Their comments are presented in Appendix M.

In addition to the collection of flight performance data, a questionnaire was given to all students at the end of the program to determine if there were any intellectual advantages through exposure to the angle-of-attack instrumentation and instruction. At the same time, the students were asked for their opinions on the angle-of-attack system and the relative emphasis by their instructors. The results of Questionnaire No. 4 (Appendix J) are presented in Table XXIV.

The first 13 questions comprised a quiz on the angle-of-attack concept and applications. The scores in Table XXIV are <u>error</u> scores; that is, the lower scores indicate a better knowledge. In almost all questions the experimental students did better than the control students. Furthermore, the experimental students in the winter quarter who had the benefit of the training manual did significantly better than the experimental student in the autumn quarter. There was one "trick" question, number 10, which was missed by almost all the control students and by a large number of experimental students. The high error scores on this question together with questions 1 and 5 suggests that the experimental students' understanding of angle of attack is perhaps superficial, and that a deeper understanding was not possible at this level of experience.

Table XXIV

Results Of Questionnaire No. 4
(Questions 1-12 are tabulated in terms of average error score)

1. By using a diagram show the meaning of the following terms:

   Pitch angle
   Flight path angle
   Angle of Attack

CA	CW	EA	EW	C	E
4.71	11.00	9.0	5.13	8.80	6.78

2. Explain the term relative wind.

CA	CW	EA	EW	C	E
.43	2.11	1.83	.25	1.47	.93

3. What is meant by angle of incidence?

CA	CW	EA	EW	C	E
1.71	2.67	1.83	1.5	2.40	1.64

4. What is the flight attitude of an aircraft when pitch angle, flight path angle and angle of attack are equal? (Assume angle of incidence = 0)

CA	CW	EA	EW	C	E
1.42	.78	1.67	1.0	1.13	1.29

5. a. What is the aircraft's attitude when just the flight path angle and angle of attack are equal?

CA	CW	EA	EW	C	E
3.57	4.45	4.33	3.38	4.43	3.79

Table XXIV - Continued

b. For this condition what is the approximate value of the pitch angle?

CA	CW	EA	EW	C	E
5.0	3.89	3.33	4.13	4.67	3.79

6. List at least three maneuvers where the pitch angle and angle of attack remain constant (but not necessarily equal).

CA	CW	EA	EW	C	E
3.86	2.45	2.33	1.38	3.27	1.78

7. Discuss briefly the relationship between airspeed and angle of attack.

'A	CW	EA	EW	C	E
.14	1.89	2.33	1.13	1.20	1.64

8. List some of the errors inherent in any angle of attack system.

CA	CW	EA	EW	C	E
2.29	2.00	1.0	1.5	2.27	1.29

9. List some of the errors inherent in the airspeed system.

CA	CW	EA	EW	C	E
2.43	2.34	1.67	1.38	2.53	1.50

Table XXIV - Continued

10. List those maneuvers which result in a different angle of attack value at the stall (assume the Cherokee 140).

CA	CW	EA	EW	C	E
10.0	7.78	6.83	6.25	9.33	6.50

11. a. Explain the meaning of "Slow Flight at Minimum Controllable Airspeeds".

CA	CW	EA	EW	C	E
1.0	.22	1.0	1.38	.60	1.21

b. How would you determine this flight condition?

CA	CW	EA	EW	C	E
2.0	2.78	.67	2.0	2.60	1.43

12. Complete the following table by placing the given numbers in A-O-A column on the appropriate place of the A-O-A scale. (Control students to complete only the airspeed column).

CA	CW	EA	EW	C	E
4.71	4.33	8.0	4.13	4.80	5.79

Table XXIV - Continued

Question 14-27 records the number of student responses.

14. How would you estimate your knowledge of the role of angle of attack and its use?

	CA	CW	EA	EW	C	E
Excellent	-	-	-	2	-	2
Good	2	1	4	6	3	10
Poor	6	8	3	-	14	3
Other	-	1	-	-	1	-

15. Do you feel you can display your understanding of it better

	CA	CW	EA	EW	C	E
By performance in the airplane	4	5	6	6	9	12
By discussion on the ground	3	2	1	2	5	3
Other	1	3	-	-	4	-

16. Estimate the emphasis given by your instructor to your understanding of angle of attack.

	CA	CW	EA	EW	C	E
Considerable	1	-	3	2	1	5
Same as for other things excluding airspeed	-	1	2	5	1	7
Same as for airspeed	3	-	1	1	3	2
Very little	4	8	1	-	12	-
Other	-	1	-	-	1	-

Table XXIV - Continued

17. How would you judge your instructor's knowledge of "angle of attack"?

	CA	CW	EA	EW	C	E
Very Good	5	3	4	3	8	7
Good	2	1	2	5	3	7
Not so good	-	2	1	-	2	1
Other	-	4	-	-	4	-

18. Estimate the value you received from the training manual on angle of attack.

	EA	EW	E
Of great value	-	1	1
Of some value	4	7	11
Of no value	-	-	-
Other	3	-	3

19. How would you judge your instructor's attitude about the angle of attack system?

	EA	EW	E
Enthusiastic	1	4	5
Indifferent	6	3	9
Negative	-	-	-
Other	-	1	1

Table XXIV - Continued

20. How do you feel about the angle of attack system as an aid in your learning to fly?

	EA	EW	E
Very good	4	4	8
Good	2	2	4
Not so good	-	1	1
Hindered	1	1	2

21. What maneuvers in your flight training do you feel it helped (if at all)? Check by numbers: 1 = most, 2 = next, etc.

Takeoff & Climbouts

	1 Most	2	3	4	5 Least
EA	2	0	1	1	-
EW	-	2	-	3	-
E	2	2	1	4	-

Cruise flight

	1 Most	2	3	4	5 Least
EA	-	-	-	-	3
EW	-	-	-	-	3
E	-	-	-	-	6

Slow flight

	1 Most	2	3	4	5 Least
EA	1	2	1	-	-
EW	2	1	2	-	-
E	3	3	3	-	-

Table XXIV - Continued

21. - continued
What maneuvers in your flight training do you feel it helped (if at all)? Check by numbers: 1 = most, 2 = next, etc.

Stalls

	1 Most	2	3	4	5 Least
EA	1	1	-	2	-
EW	-	1	2	2	-
E	1	2	2	4	-

Approaches and landings

	1 Most	2	3	4	5 Least
EA	-	1	2	-	-
EW	3	1	1	-	-
E	3	2	3	-	-

22. Where in your flight training do you feel it helped (if at all)? Check by numbers as in above question.

Pre-solo

	1 Most	2	3	4	5 Least
EA	3	1	-	-	-
EW	5	-	-	-	-
E	8	1	-	-	-

Solo

	1 Most	2	3	4	5 Least
EA	1	1	-	-	-
EW	-	5	-	-	-
E	1	6	-	-	-

Pre-cross country

	1 Most	2	3	4	5 Least
EA	-	1	1	-	-
EW	-	-	2	-	-
E	-	1	3	-	-

Table XXIV - Continued

22. - continued
Where in your flight training do you feel it helped (if at all)? Check by numbers as in above question.

	Cross Country 1 Most	2	3	4	5 Least	Final preparation 1 Most	2	3	4	5 Least	Not at all
EA	-	-	-	1	-	-	1	-	-	1	1
EW	-	-	-	2	-	-	-	-	-	2	-
E	-	-	-	3	-	-	1	-	-	3	1

23. Did you have any difficulty in using airspeed information?

	EA	EW	E
Yes	1	2	3
No	5	6	11

Table XXIV - Continued

24. Do you believe you could fly with:

Just angle of attack alone

	EA	EW	E
Yes	5	6	11
No	2	2	4

Airspeed alone

	EA	EW	E
Yes	7	8	15
No	-	-	-

25. If both angle of attack and airspeed information were available to you, estimate the relative value of their use in percentages?

% A/A	10	20	30	50	60	70	75	80
% Airspeed	90	80	70	50	40	30	25	20
EA	-	1	1	1	2	-	-	-
EW	1	1	-	2	1	1	1	1
E	1	2	1	3	3	1	1	1
I*	-	-	-	1	2	1	1	1

*Instructors (winter quarter)

Table XXIV - Continued

26. Lid maintenance or reliability of the angle of attack system have any bearing on your progress?

	EA	EW	E
No	4	6	10
Yes	3	2	5

27. What opinions do you have regarding your involvement in this angle of attack program?

	EA	EW	E	I
Constructive	4	6	10	6
Informative Only	2	2	4	-
Indifferent	-	-	-	-
Negative	1	-	-	-
Other	-	-	-	1

SUMMARY

It is necessary to qualify this summary with the request that this experimentation program be viewed as an exploratory effort rather than as definitive research. Many unforeseen problems arose that had the affect of weakening the results.

The development of reasonable instructional techniques took place throughout the Autumn Quarter, or first half of the program. The instructors were not thoroughly indoctrinated in the use of angle-of-attack, nor was there sufficient basis or time to do so prior to the Autumn Quarter. In evolving the instructional techniques, mistakes were inevitable and had unmeasurable effect on the students.

Instrumentation failure or unreliability in the Autumn Quarter led to natural suspicion for both instructors and students. Changes in angle-of-attack display further confounded the measurement of the system's effectiveness. The flight check scoring systems underwent revision in the Autumn Quarter.

Although many of the above problems were not present in the Winter Quarter, three significant factors remained, two of which were inherent in the FAA guidelines for the program. The first factor is that the airspeed indicator was to be used in addition to the angle-of-attack system, and the private pilot certification flight was to be based on the use of the airspeed instrument. The effect of this requirement, though not apparent through most of the Autumn Quarter, was quite serious when fully realized. The instructor acted as if his first obligation was to prepare his student for the private pilot certification flight. When he introduced airspeed, it was presented as a primary instrument. Whatever had been taught using angle of attack was now relearned using airspeed. Some attempt was made to correlate the two information sources. On check flights it was almost impossible for the check pilot or examiner to determine which instrument the experimental student was using. The lack of difference in performance on the final flight check, with and without the angle of attack, probably was caused by sole use of the airspeed. The emphasis on the use of airspeed with one experimental student was observed by the GADO Inspector (see narrative in Appendix M).

The second factor was the FAA guideline to use the same instructional syllabus for both control and experimental groups. Although this guideline allowed some flexibility, it was adhered to through the early part of the Autumn Quarter. When it became apparent that the airspeed was playing a primary role (particularly when the angle-of-attack system malfunctioned) the instructional "damage" was done.

At the beginning of the Winter Quarter, the instructors were asked not to mention airspeed at all until the student was ready to solo, and when introduced, airspeed was to be considered as a back-up for the angle-of-attack system.

The third factor, and most difficult of all, is the time and effort required to introduce and indoctrinate the flight instructors in effectively teaching angle of attack. Many instructors believed that angle of attack is not a difficult concept or system to teach, but that it requires repeated exposure and experience for full appreciation. But, to what extent can this appreciation be developed in the instructor for the device to be effectively taught? It is interesting to note that of the two instructors who had the opportunity to teach in both quarters, the comment of one of the instructors (see I2 in Appendix L) was only mild at the end of the Autumn Quarter, but quite enthusiastic at the end of the Winter Quarter.

The instructors' relatively little experience as flight instructors also had an unmeasurable effect. When the instructors realized the large stall margins for the "normal" approach speed of 85 mph, they tended to fly slower approaches in both groups. It is believed that if they did not actually teach slower approaches, they did not discourage slower approaches. Thus, it is possible that the lack of differences between control and experimental groups may be partly attributed to a carry-over effect by the flight instructors.

The experimental students developed a better understanding of the concept of angle of attack and basic aerodynamics related to aircraft performance. Control students felt that their instructors gave little emphasis to the meaning of angle of attack. This seems to be characteristic of the traditional flight training syllabus.

In this case, lack of understanding may be synonymous with lack of appreciation. Understanding and appreciation depend strongly on the instructor relationship and the flight experiences created for or encountered by the student. The perspective that the primary student pilot has developed at the end of 40 hours of traditional flight training may be inadequate to fully appreciate the value of angle of attack information.

Finally, it is strongly believed that the current standards and training aircraft used for private pilot certification do not require the proficiency that may be gained through the use of angle-of-attack instrumentation. The standards for private pilot certification permit a range of performance that is gross, variable, and subjective. The proficiency that is required at one flight school may be different than at another. A criterion often heard is whether the student is safe, rather than some measure of excellence or precision. The development of a more objective and complete flight test was one of the accomplishments of this experimental program.

Although the type of aircraft used for student training are no longer of the "climb, cruise, and glide at the same airspeed" type, their speed and weight range is sufficiently limited ($V_{cruise} \approx 2V_{so}$) so that a student needs to remember relatively few airspeeds. A student

polot quickly learns to associate airspeed with performance, which fortunately may be adequate for the current trainers. Aircraft performance in the heavier and more complex types is much more sensitive to weight and configuration and hence the difficulty is greater in attempting to relate a larger number of airspeeds to performance. Angle-of-attack information is then appreciated.

CONCLUSIONS

1. Evaluation of the effectiveness of angle-of-attack instrumentation in the training of student pilots to private pilot certification was adversely affected by permitting the simultaneous use of the airspeed indicator.

2. Under the conditions of this program, the angle-of-attack instrumentation did not facilitate flight training based on time to first solo, total hours, or overall flight-check performances.

3. Flight-check performances, when analyzed by maneuvers, indicated significant differences in favor of angle of attack in the performance of slow flight, downwind leg for normal landings, and final approach for short-field landings.

4. The rate of learning of the angle-of-attack students was decreased by the need to teach and transition the student to the use of airspeed information although total flight time remained unchanged.

5. The use of angle-of-attack instrumentation requires new, but not difficult, instructional techniques and revision of the traditional training syllabus.

6. The advantages of angle-of-attack instrumentation as determined by questionnaire and qualified observers are:

   a. It develops a better intellectual foundation of basic aerodynamics and aircraft control.

   b. With sufficient exposure and experience, flight instructors develop greater appreciation for the system in that it provides reliable stall margin and optimum aircraft performance information.

   c. Exposes clearly the limitations of airspeed information in providing aircraft performance information.

7. The disadvantages of the angle-of-attack instrumentation appear to be:

   a. The inability of the student and instructor to measure the small, but significant, changes in angle of attack through the visual or kinesthetic senses, which leads to a natural reluctance to accept angle-of-attack information.

   b. The above reluctance or distrust is considerably magnified if there are instrumentation malfunctions or contradictions with the airspeed indicator, even though the airspeed may be the source of error.

8. Malfunctions of the angle-of-attack instrumentation in the first half of the program had an adverse effect on some of the instructors and students, which further confounded the interpretation of the flight performance scores.

9. The angle-of-attack instrumentation used throughout the second half of the program operated with complete reliability, with instructor acceptance vastly improved.

10. The design and information content of the display dial developed for the second half of the program was considered excellent. It contained all the relevant information of the airspeed indicator except V_{NE}, the never-to-exceed speed.

11. Use of the Pilot Performance Description Records, though in need of further refinement, was essential in evaluating check flight performances.

RECOMMENDATIONS

1. Evaluation of angle-of-attack instrumentation in the training of student pilots to private pilot certification should be repeated and conducted under the following conditions:

    a. The experimental group using the angle-of-attack instrumentation should not see or use the airspeed indicator throughout the entire training program.

    b. The size of the control and experimental groups should be increased to 30 students in each group.

    c. Instructors in the experimental group should not be teaching in any other group.

    d. Orientation and standardization of the instructors, prior to teaching in the experimental group, should include the experience of teaching at least three students using a syllabus especially designed for the angle-of-attack students.

    e. There should be a minimum of four flight checks for each student throughout the training program.

2. Any future evaluation of angle-of-attack instrumentation in the training of student pilots should attempt to determine:

    a. The proficiency level in excess of current private pilot standards that can be attained in, say, 40 hours.

    b. The lowest amount of flight time necessary to pass current private pilot standards.

    c. The average number of hours to learn to use airspeed, if all training to private pilot standards is with angle of attack only.

    d. The effect of the location of the display dial.

    e. The effect of the display's physical configuration (e.g., horizontal, circular, vertical, etc.).

    f. The effect of varying the display dial's information content (e.g., color coding, percentages of V_{SO}, index marks).

    g. The effect of colored lights activated by the angle-of-attack system to improve peripheral vision response.

3. Angle-of-attack instrumentation should be evaluated in the training of advanced students or pilots for operations in STOL aircraft or conditions.

4. The angle-of-attack instrumentation should be evaluated under turbulent wind conditions to determine the trade-offs or desired sensitivity in display needle response under both approach and cruise conditions (i.e., Is it possible from needle fluctuations to assess the controllability margins and should there be increased dampening when in cruise flight?).

APPENDIX A

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APPENDIX B

ANGLE-OF-ATTACK TRAINING MANUAL

I. INTRODUCTION

Knowledge of the concept of angle-of-attack in aircraft performance appears to be regarded by most pilots as something academic. If so, it might be assumed that there is little application of this highly important concept! It would be hard to believe that people can be taught to fly an airplane and not understand angle-of-attack. It is easy for an instructor to rationalize why this may be true: There has been no reliable instrument to measure angle-of-attack (Up until the past few years!). Instead, all flight instruction relating to aircraft performance was based on airspeed, attitude, and power control.

Thus, airspeed became a very important factor in teaching one to fly an airplane. But really, how good and how reliable is the airspeed instrument? And how does it relate to aircraft performance? Given an angle-of-attack instrument in the airplane, how can it be used as a basic measurement of aircraft performance and to teach one to fly an airplane? How does angle-of-attack information relate to airspeed information?

Basically and briefly, angle-of-attack information always indicates to the pilot his operating margin from the stall condition. Most importantly, it always indicates, without ambiguity, the exact angle of attack to use to fly the airplane for such varying flight performances as best rate of climb, maximum angle of climb, slow flight at minimum controllability, short field landings, optimum engine-out performance, maximum range, and maximum endurance.

The purpose of this manual is to answer and fully explain the above questions and statements. Specifically, this manual has been written to assist both students and flight instructors in the use of the Monitair angle-of-attack instrumentation. Section II reviews the basic aerodynamics concerning angle of attack. Section III describes the instrumentation installed on the Piper Cherokee (PA-28-140) aircraft. Section IV discusses the pilot techniques found to be most effective with this particular angle-of-attack system.

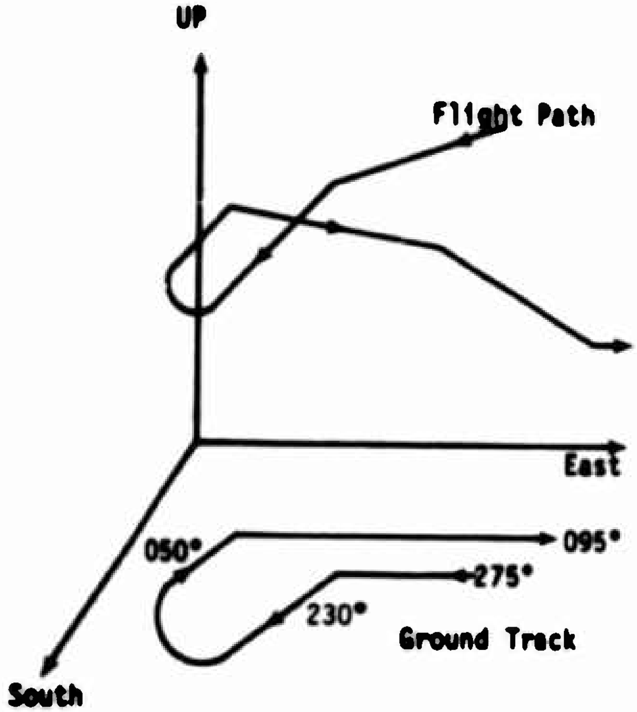
II. BASIC AERODYNAMICS

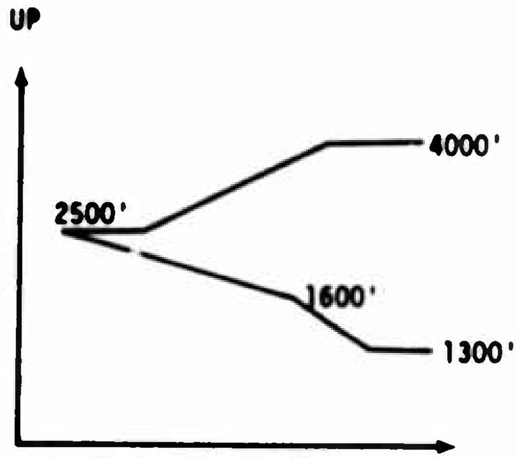
Let's begin with some very fundamental and important definitions. These definitions are illustrated in Fig. 1-3.

Flight path. The path described by the airplane as it travels in the three-coordinate space on and above the earth's surface.

Ground track. The projection of the aircraft's flight path onto the earth's surface.

Vertical flight profile. The projection of the aircraft's flight path onto a plane perpendicular to the earth's surface.





Vertical Flight Profile

FIGURE 1

Relative wind. The flight path of the aircraft. The flight path and relative wind are, for all practical purposes, the same thing except for direction. Because the aircraft is moving in one direction the relative wind (created by the aircraft) is moving in the opposite direction.

Flight path angle. The angle between the flight path and the horizontal coordinate at the aircraft. This horizontal coordinate will henceforth be called the horizon.

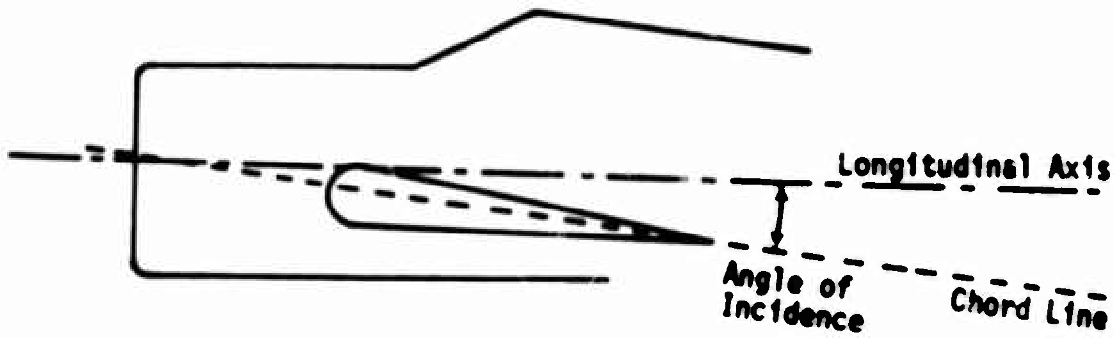


FIGURE 2

Pitch angle. The angle between the longitudinal (or roll) axis and the horizon. (This is the easiest for the pilot to see as it is the angle of the "nose" above or below the horizon.)

Angle of incidence. The angle between the longitudinal axis and the chord line (a constant for any given airplane, and usually very small).

Angle of attack. The angle between the flight path and the chord line (or, the angle between the flight path and the roll axis, if it can be assumed that the angle of incidence is zero or very small.)

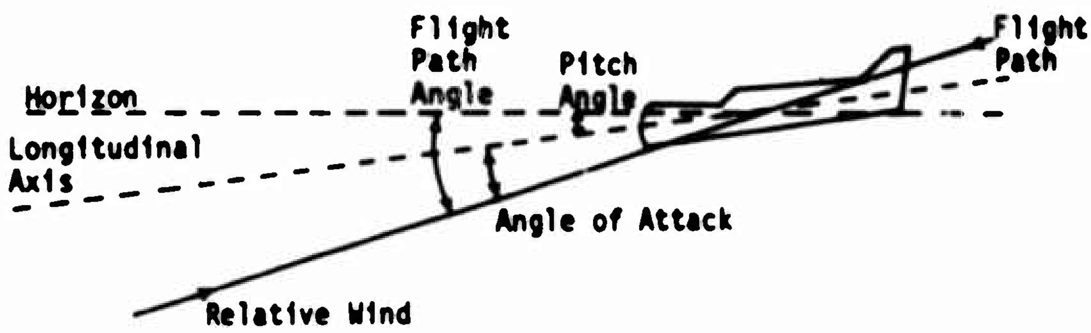


FIGURE 3

Note from the above Fig. 3 how these angles are related. Though these angles are simply defined there exists considerable confusion among students and novice pilots. Figures 4 and 5 show how pitch angle remains the same but the angle of attack is different. This can be accomplished by reducing power and increasing up elevator pressure to hold nose (pitch) constant. Thus with less power and with pitch constant, the flight path angle has steepened. Since pitch is constant the angle of attack has increased.

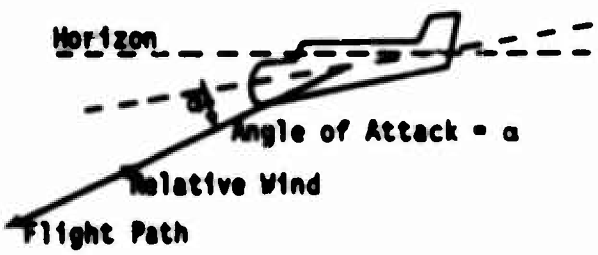


FIGURE 4

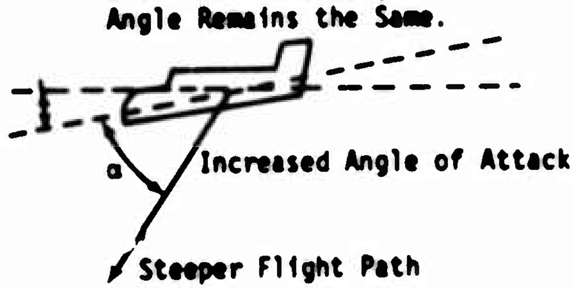


FIGURE 5

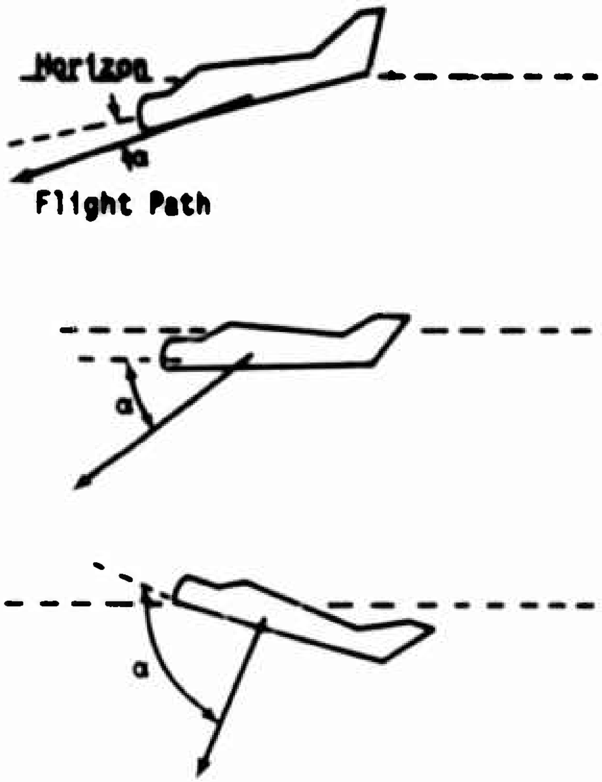
Now the question can be asked: how does one change the aircraft's flight path and/or the angle of attack? If we consider just the vertical flight profile, there are two controls available to the pilot: elevator (or "pitch") and throttle (or "power"). Both are used in combination to affect flight path and/or angle of attack. Figure 6 shows the effect of constant pitch attitude and increasing power. Figure 7 portrays power off, increasing pitch, and increasing angle of attack.

FIGURE 6

Pitch angle is maintained constant in a slightly down angle

Power is increased, thrust is increased

Airspeed increases and altitude decreases rapidly



Power off, aircraft descending

Increasing pitch up attitude by increasing up elevator pressure

Flight path angle increasing (Sink rate increasing)

And even faster increasing angle of attack, α

A rapid slowing up of airspeed

Finally, at the critical angle of attack, the aircraft stalls

FIGURE 7

Some of these concepts could more rigorously be demonstrated by the use of the "classical" force diagram (Fig. 8) in which the aircraft is in "unaccelerated level flight equilibrium."

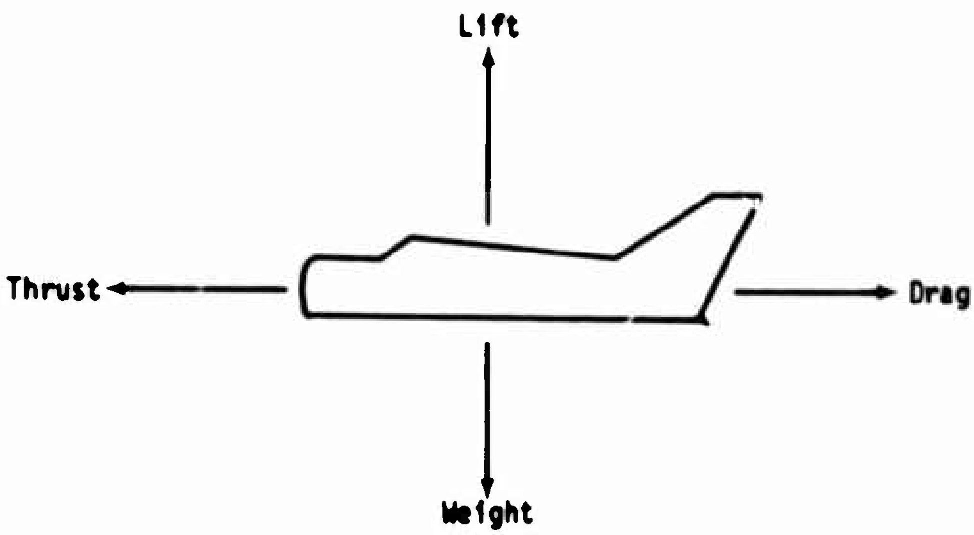


FIGURE 8

However, the simplicity of this standard representation is extremely misleading. For example, this diagram shows the forces to be perpendicular and parallel. But the big question is: perpendicular and parallel to what? If you say the longitudinal axis, or the horizontal coordinate, join the many other wrong guessers! If you answered by saying "all forces must be balanced about the flight path," congratulations! Let's try an example; how would you draw the forces on the aircraft when in either a constant-speed climb or descent?

Figure 9, which shows a descent, can be used to remind you that the weight of the aircraft is the only force which acts in only one direction, namely, down toward the center of the earth. Thrust, drag, and lift all act either perpendicular or parallel to the flight path (or relative wind, if you like).

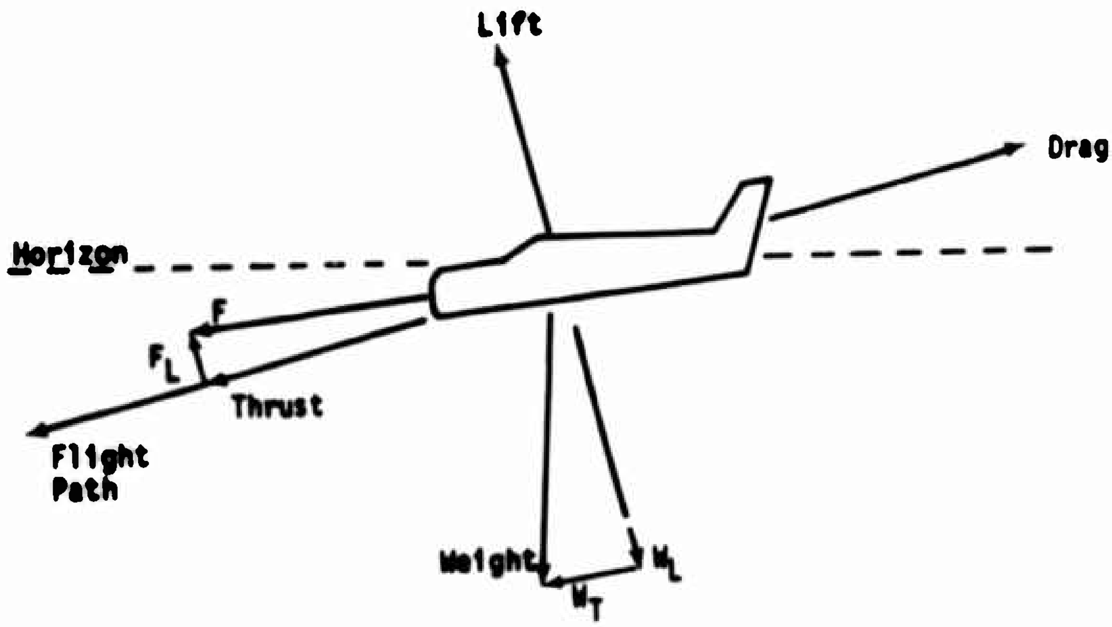


FIGURE 9

The next question that can be asked is: what is meant by equilibrium of these forces? Equlibrium usually means that condition when all forces sum to zero. This summing process cannot be done unless the coordinate system is well defined and all forces not perpendicular or parallel to the coordinate axes are resolved into perpendicular and parallel components.

Thus in Fig. 9, the weight force must be resolved into two components; i.e., one perpendicular to flight path and opposite to the lift force, the other parallel to flight path and in the same direction as the thrust force. Similarly the propeller force resolves itself mostly into thrust and some into lift.

In order to maintain constant velocity, only the thrust force need be reduced (by the pilot) because of the parallel weight component helping to balance out the drag force. It should be pointed out that the lift force adjusts itself to some fixed value as a consequence of the speed and attitude of the aircraft. This adjustment of the lift force is not at all obvious.

Lift as a concept can be difficult to fully understand. For this reason it will be discussed in detail showing its basic dependence on angle of attack.

No doubt all readers know that lift is an upward force; but what does lift depend upon, or, in other words, what physical characteristics of the aircraft or environment can affect the amount of lift force to be present?

Most precisely,

$$\text{Lift} = C_L \tfrac{1}{2}\rho V^2 S \quad ,$$

where

V = velocity of the aircraft,

S = wing surface area,

ρ = air density, and

C_L = coefficient of lift, a dimensionless "catch all" of all the other aerodynamic factors affecting lift.

Thus, if one increases the speed of the aircraft, the lift increases by more than the square of the speed increase.

Increasing wing area increases lift.

Decreasing the air density decreases lift.

For any given situation we would like to consider a particular airplane (S = constant), the same atmospheric environment (ρ = constant), and the aircraft in equilibrium flight (V = constant), which leaves only one factor to investigate; i.e., C_L.

For our purposes it is sufficient to say that C_L can be changed by the pilot if the pilot changes the aircraft's angle of attack; that is,

C_L is directly related to angle of attack (see Fig. 10).

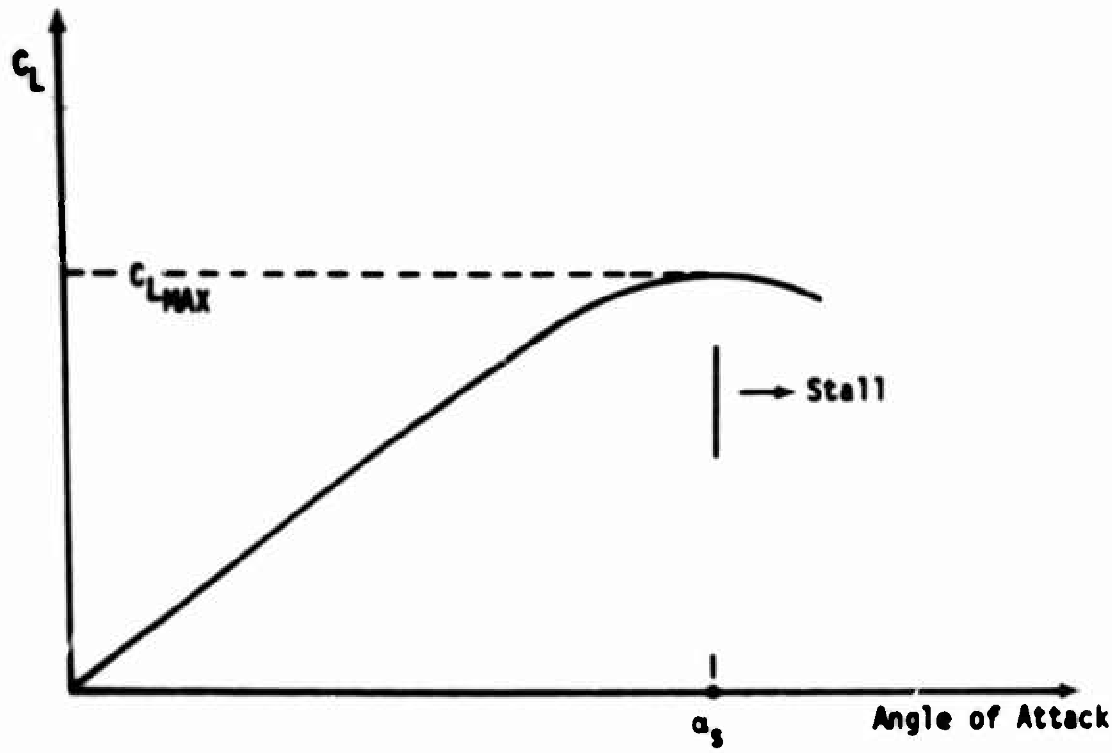


FIGURE 10

This graph indicates that the pilot can increase his angle of attack and hence increase C_L, but if he does so and if the pilot is to keep the airplane at the same altitude, airspeed will be reduced and thrust adjusted as necessary. When the angle of attack reaches the maximum C_L, any further increase in angle of attack results in the separation of smooth air flow over the top surface of the wing. This condition is called the stall. The angle of attack value at which this stall occurs is called the critical angle of attack. Note well that C_L, and hence lift performance, depends on angle of attack and not airspeed. Until recently the pilot had no instrumentation which displayed angle-of-attack information. As a result he was taught that there was a relationship between angle of attack and airspeed: the slower the airspeed, the greater the angle of attack. "By using the airspeed indicator he can change the angle of attack!"

I say "change" rather than "control" because the airspeed can vary a great deal for a single value of angle of attack because of such factors as flap and gear configuration, gross weight, bank angle, and temperature. The pilot rarely knows the desired airspeed for any given

combination of these factors. As a result he compensates for this ignorance by flying much faster than he has to! Why? He knows that these factors increase the stalling speed. So in order to keep his "safe" margin from the stall he flies faster. Let's say some more about this "stalling speed." An airplane doesn't really stall because the airspeed drops too low - it stalls because the angle of attack increases beyond a certain value. And here's the most important idea of all; this critical value of angle of attack is a constant for a given wing and flap setting. In the Cherokee 140, the critical angle of attack is one and the same for all flap settings, as well as for all maneuvers. There is an airspeed that can be associated with the stall, but if there is a change in gross weight C.G. location, bank angle, or power level, the indicated stalling airspeed changes too! Not so with the angle of attack; it is independent of all these factors.

We repeat: The critical angle of attack at which the stall occurs is a constant for the airplane regardless of gross weight, air density, bank angle, and power level. It is important that this characteristic be fully appreciated.

The last fundamental to be discussed here is the effect of the use of flaps on angle of attack; refer to Fig. 11, where the C_L curve is drawn for both conditions (i.e., no flaps and full flaps).

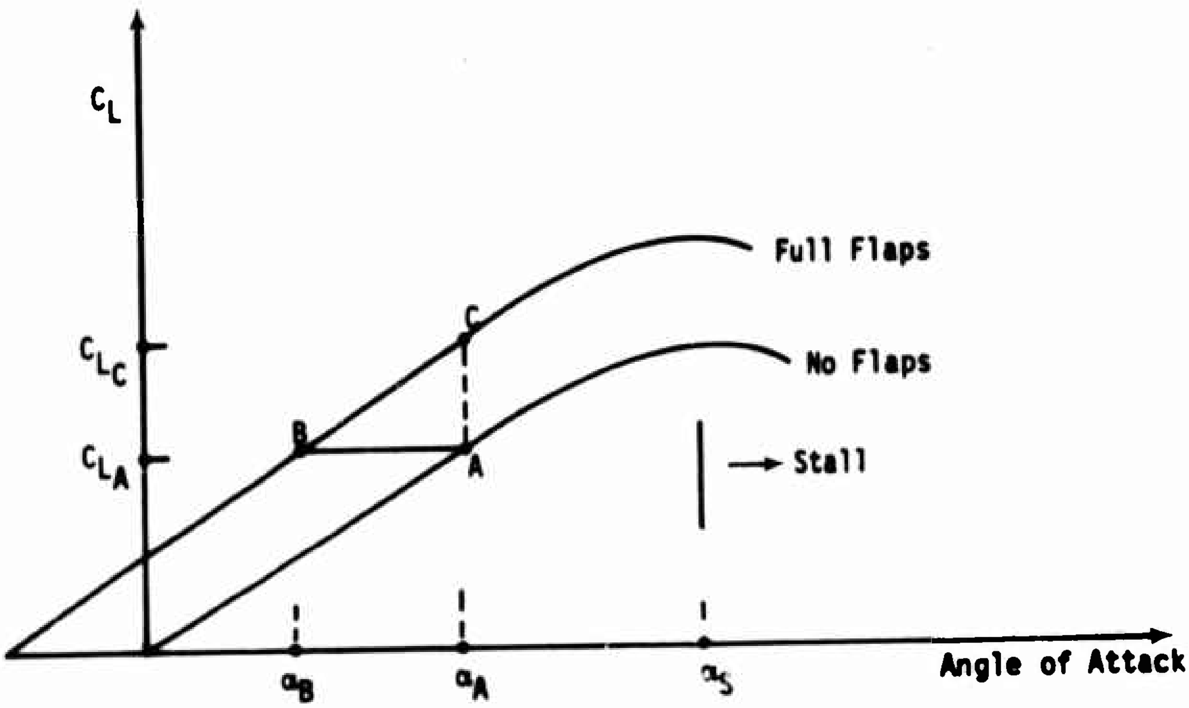


FIGURE 11

If we add flaps while at the same time try to keep C_L constant then we go from point A to point B. Note that this results in a smaller angle of attack and greater margin from the stall. On the other hand, if we keep the angle of attack constant (approximately the same stall margin) and go from point A (no flaps) to point C (full flaps) than we have a greater C_L, which at constant altitude allows the airspeed to be much lower. It is this lower airspeed but same stall margin that is sought in landing the airplane.

The major point that must be made here is that angle-of-attack information always tells you your operating margin from stall. Finally, angle-of-attack information more precisely identifies those conditions for best rate of climb, maximum angle of climb, slow flight at minimum controllable airspeed, short field landings, optimum engine out performance, maximum range, and maximum endurance.

III. DESCRIPTION OF THE INSTRUMENTATION

The angle-of-attack instrumentation currently being evaluated was manufactured and supplied by the Monitair Corporation, Teterboro, New Jersey. The system is to provide the pilot with a positive visual indication of the maximum performance capability of the aircraft and also to alert the pilot of an impending stall. A complete system has been installed on each of three Piper Cherokee 140's belonging to The Ohio State University Department of Aviation. Each system consists of the units or assemblies listed below.

(1) Wing transmitter (or vane) assembly. This assembly is located on the left wing's leading edge and is the sensing element of the system. It contains a movable vane directly coupled to a pylon-mounted potentiometer. The vane senses and moves with the air flow pattern ahead of the wing, which varies directly with changes in wing angle of attack. The potentiometer translates the vane movement into a corresponding electrical signal. This electrical signal is then applied to the computer unit.

(2) Computer unit. The computer unit is made up of two sections of electronic circuitry. The angle-of-attack section contains a bridge circuit which transfers the vane signals into properly scaled voltages for the indicator unit. The stall warning section contains an electronic switch which activates the existing red stall warning light.

(3) Indicator unit. The angle-of-attack indicator unit is a DC 0 to 1 milliammeter mounted on the glare shield in front of the pilot. The scale is calibrated and color-coded to designate specific performance characteristics of the Piper Cherokee 140.

(4) Stall warning light system. The stall warning light system is the existing factory-installed equipment. The stall warning light is located in the middle of the instrument panel in front of the pilot.

Of greatest concern to the pilot is the interpretation and use of the indicator unit. Figure 12 is a diagram of the face of this display unit. The first thing to note is that the stall region or maximum angle of attack is at the left edge.

Proceeding from left to right, or decreasing angle of attack, the markings on the display unit will be defined, leaving to Section IV the pilot techniques to be used with these markings.

The black and white "barber pole" region immediately to the right of the stall region is the stall warning region. When the angle of attack indicates in this region, the red stall warning light should be on. The yellow SLO region merely indicates caution and will often be used for slow flight maneuvers.

The A/C index mark represents the angle of attack for maximum angle of climb.

The blue region with the letter C/D in the center corresponds to the proper angle of attack for best rate of climb and normal descents for landing.

The parallel green and white regions can be used for slow cruise performance with the right edge of the center white bar corresponding to the maximum speed at which flaps can be operated.

The solid vertical green region indicates normal cruise performance at 65% power. The width of this region is related to the variation in angle of attack that will arise for constant power setting as the aircraft's gross weight changes. The left edge of the solid green represents maximum gross weight, and the right edge corresponds to minimum gross weight (one small person and about ten gallons of gas).

The green and white "barber pole" region corresponds to airspeeds which exceed the rough-air maneuvering speed of 129 mph. Thus, the left edge of this green and white region is not to be exceeded when maneuvering in rough air.

IV. PILOT TECHNIQUES

The effective use of the angle of attack is best achieved by the pilot when he uses his knowledge of the basic aerodynamics to anticipate the effect of his control actions. This section will describe the behavior of the angle-of-attack instrumentation for all of the relevant maneuvers and flight performance.

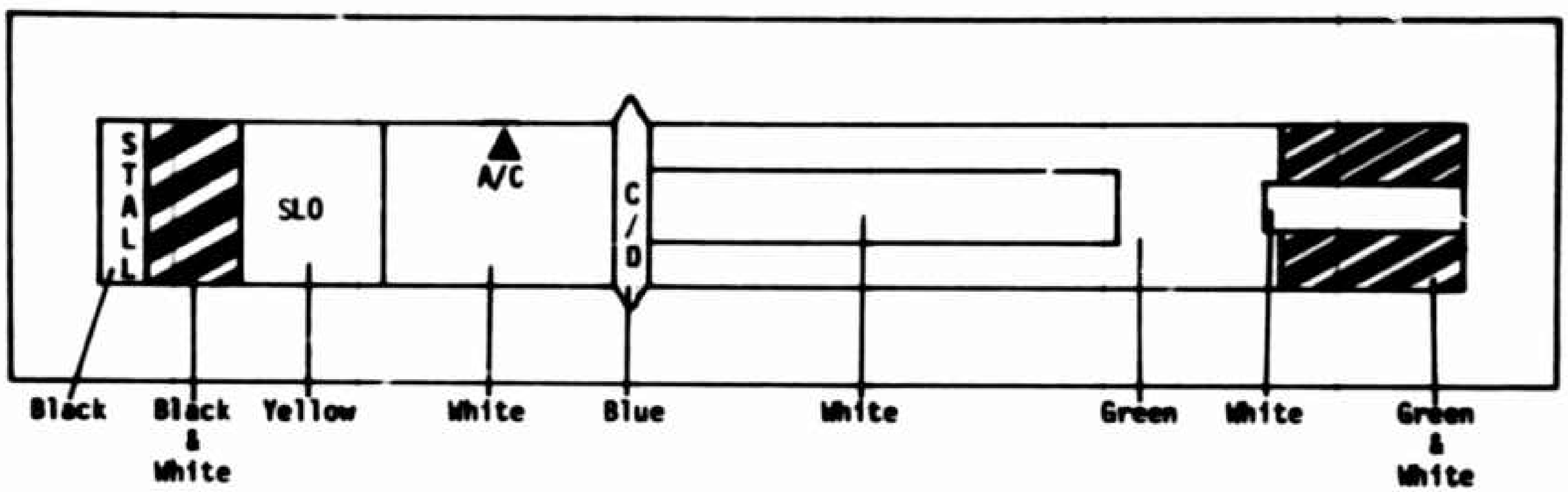

STALL
SLO
A/C
C/D
Black
Black & White
Yellow
White
Blue
White
Green
White
Green & White

FIGURE 12

Take-Off and Climb. Although the airflow on the angle-of-attack vane is adequate during the latter part of the take-off roll, it will probably indicate in the green regions until the airplane is lifted off the ground. Therefore, it is not to be used to determine when to lift off or the proper pitch attitude immediately after take-off. The take-off is performed normally with rotation of the nose at about 70 mph. A climb attitude is established and held constant with respect to visual horizon references. The desired climb attitude is verified by refering to the angle-of-attack display. A normal climb at best rate of climb occurs when the needle is in the blue region. For the angle-of-attack needle to be in this region it is quite common for the airspeed to be holding steady at some value ranging from 80 mph to 95 mph, depending on weight, temperature, altitude, etc.

It may be desirable after the initial climb to improve "over-the-nose" visibility. Lowering the nose decreases the angle of attack, the needle then moves to the right, and the airspeed increases.

If the pilot attempts to watch the angle-of-attack needle too closely during the lift-off, the following interesting but undesirable performance results:

Immediately after lift-off, the angle-of-attack needle suddenly moves far left into or near the yellow region. But if the proper pitch attitude is held constant, then shortly the needle moves back to right indicating the correct angle of attack. This sudden increase in the angle of attack at lift-off demonstrates in an almost slow motion fashion the basic aerodynamics of an airplane transitioning from level flight to a steady-state climb. Consider the following sequence of events: the airplane is rolling for take-off. Pitch angle and flight path angle are zero. The wing's angle of attack at this point is very small, that is, being equal to the angle of incidence. Thus, in order to initiate the climb, the nose is rotated off the ground and in this short instant the angle of attack has suddenly increased because the flight path is still horizontal. With the increased pitch angle and angle of attack, wing lift together with an upward component of thrust combine to provide an upward force which is greater than the aircraft's weight and the aircraft accelerates upward. Holding the pitch attitude constant, the flight path now changes from horizontal to that of turning upwards where it stabilizes for the given power condition. Angle of attack is now less than at rotation, and remains constant for power and pitch conditions throughout the initial climb.

Straight and Level Cruise Flight. When leveling off for straight and level cruise (always using visual horizon references), the angle-of-attack needle should move to the right into the solid green region if power is set for 65%.

Level Flight Turns. It is most gratifying to have a basic flight maneuver, such as a turn, immediately reflect a fundamental aerodynamic

principle. As the turn is made by banking the wing, lift on the wing is reduced. At reduced lift, the plane would descend, but since level flight is desired, the reduced lift is compensated by increasing the angle of attack. In the turn, then, rather than have the plane descend with pitch-low attitude, back pressure is applied to the elevator control thereby increasing the angle of attack, the horizon picture is constant and "level" and the angle-of-attack needle has moved to the left. When rolling out of the turn, the angle-of-attack needle should move back to the right by releasing the back pressure.

How much the angle of attack is increased depends on the magnitude of the bank angle; i.e., the steeper the bank angle, the greater the back pressure, the greater the angle of attack, and the farther to the left goes the angle-of-attack needle.

Slow Flight at "Minimum" Controllable Airspeed. This maneuver is defined by the FAA as controllable flight at an airspeed "sufficiently slow so that any reduction in speed or increase in load factor would result in immediate indications of an imminent stall." The guesswork in determining this speed condition is eliminated with the angle-of-attack system. Slow the airplane, holding altitude constant, so that the angle-of-attack needle moves left into the black-and-white stall-warning region. For this maneuver it is preferred that the needle stay on the right edge of the black-and-white region. The red stall-warning light should be on or flickering on and off. Constant visual horizon references should be maintained. It is interesting to note that a level turn at this attitude decreases the stall margin (i.e., needle moves left) only a needle width for a bank angle of 15°. Only as the bank angle reaches 30° does the needle move farther left into the stall region, and a slight buffet is felt.

The airspeed could be reading anything from 30 to 60 mph, depending on weight, temperature, altitude, bank angle, and flap setting.

Stalls. All the stalls, without exception, occur when the angle-of-attack needle moves into the stall region. The greatest problem in using the angle of attack for stalls (and really not unique to angle of attack) is entering the maneuver at excessive airspeed. With too fast an entry, the student tries to bring the needle to the left edge too quickly by continually raising the nose. The result is an extremely unrealistic nose-high attitude. This may be called "zooming" into the maneuver. It is most important to learn the minimum pitch-up attitude at the stall and this can only be done if the entry is performed slowly and smoothly.

The stall recovery is primarily accomplished by releasing back pressure and allowing the nose to lower and the angle-of-attack needle to move right into the yellow. As power is applied, a climb attitude can be established and the angle-of-attack needle placed on the A/C index. To minimize altitude loss, the angle-of-attack needle should not go any farther to the right than the A/C index.

Maximum Glide, Power Off. As in all descents, the angle-of-attack needle should be kept in the blue region for maximum glide performance. This angle of attack corresponds to maximum lift-over-drag ratio.

Normal Approaches and Landings. The "normal" approach specified in The Ohio State University syllabus calls for an approach with two "notches" of flaps on final. Using the angle-of-attack system should enable the pilot to fly his attitude and visual pictures with greater consistency and accuracy. The angle-of-attack concept places considerable emphasis on constant pitch attitude and the use of throttle to control flight path and hence angle of attack.

The recommended procedure begins with the downwind leg. The airplane is slowed so that the angle-of-attack needle is in the white flap-operating range. Aircraft is trimmed to relieve control wheel pressures. With pitch attitude about level the first notch of flaps is put on. Note how the angle-of-attack needle has moved to the right. Thus the effect of flaps was to increase the margin from the stall. It is now necessary to slow the airplane so as to get the angle-of-attack needle in the blue region. This can be done on the base leg by reducing power and with a very small pitch-up change. Since power controls flight path and rate of descent, too great a power reduction may lead to an increasing "sink" and increasing angle of attack. Although it may be desirable to increase the angle of attack so as to get needle to the left, one must remember the basic objective of the approach is to develop a visual picture of the runway and related references. Therefore, pitch angle should be maintained as constant as possible, with flight path and sink being controlled by throttle.

After the turn on to base has been made, the second notch of flaps is used. This addition of flaps again affects the angle of attack and the needle moves to the right. By responding with a reduction of throttle, trim change, and constant pitch attitude, the needle should move back to the blue region. The visual picture should be emphasized.

If the approach is high on final and power is reduced to idle, the only control left to affect the angle of attack is pitch. This is undesirable since this often results in a "roller coaster" picture of the runway, making it very difficult to judge altitude, closure rate, sink rate, and wind effects.

Short Field Landings. The short field landing techniques is essentially the same as for normal landings with the following two major exceptions:

(1) Full flaps are used. The first notch can be put on downwind; the second and third notches on base.

(2) The appropriate angle of attack index on final is the A/C mark.

Wind conditions may alter this procedure. For strong gusty or cross winds, the approach can be modified for better controllability by using less flaps and/or smaller angle of attack.

APPENDIX C

FLIGHT TRAINING SYLLABUS

Stage 1: Presolo and Supervised Solo

Orientation Phase

Period 1

Discuss the forces on the airplane in flight, axis of rotation, function of controls (including trim tabs and flaps), and instruments. Demonstrate preflight checklists, starting procedures, radio check, pre-takeoff check, and orient the student to the practice areas.

Period 2

Review of Period 1. Discuss and practice pre-flight inspection, starting, radio check, pre-takeoff procedures and flight instruments. Introduce and practice straight and level flight, level turns, straight climbs, climbing turns, straight glides, gliding turns. Before returning to the airport, call University Tower (121.1) to obtain surface winds and the runway in use. Introduce and practice taxiing and the proper use of controls while taxiing.

Period 3

Discuss the principles of basic instrument flying. Demonstrate use of instruments and controls and explain function of each. Devote flight portion equally to visual and instrument flight with practice of straight and level turns.

Pre-Solo High Work Phase

Period 4

Discuss and review visually and on instruments the previous fundamentals such as straight and level and level turns and the use of the artificial horizon and directional gyro. Practice coordination exercises, steep turns, takeoff and departure stalls, approach to landing stalls, torque correction in relation to airspeed, power changes, and takeoffs. Demonstrate the use of trim tab and its function.

Period 5

Discuss torque correction and the use of trim. Review fundamentals visually and on instruments the maneuvers of Period 4.

Demonstrate spin entry from a stall and spin recovery techniques.

Period 6

Discuss local ground and air traffic patterns and rules. Introduce takeoffs. Demonstrate and practice slow flight, practice takeoff and departure stalls, approach to landing stalls, coordination exercises, and introduce power-off landing on return to the airport. On simulated instruments, practice straight and level climbing turns and gliding turns.

Period 7

Discuss air courtesy and discipline. Practice visually and on-instruments climbing and gliding turns, slow flight, and takeoff and departure stalls.

Pre-Solo Low Work Phase

Period 8

Discuss and practice takeoffs and landings, traffic patterns and traffic-pattern entry, taxi patterns, low-altitude forced landings on takeoff, forward slips, and crosswind takeoffs and landings.

Period 9

Discuss and practice power-on and power-off stalls visually and on instruments. Review straight and level and turns on simulated instruments. Demonstrate power-off spot landing.

Period 10

Discuss and practice slow flight and high-altitude emergencies. Call Columbus radio for winds aloft. Practice takeoffs and landings. Review crosswind landings and takeoffs.

Period 11

Discuss and practice traffic-pattern entry, slips, use of flaps, takeoffs and landings.

Period 12

Discuss traffic patterns and emergencies. Call Columbus radio for current Mansfield weather. Practice takeoffs and landings.

Period 13

Discuss traffic patterns and emergency procedures. Practice takeoffs and landings.

Solo Phase

Period 14

Discuss and practice takeoffs and landings including at least one emergency on takeoff and one crosswind landing. The instructor will supervise three solo takeoffs and landings. If the student is not ready to solo, this period may be repeated with practice on maneuvers either out of or in the traffic pattern on which the student may be deficient until the student is ready to solo. (First supervised solo.)

Period 15

Instructor will supervise a minimum of five solo takeoffs and full stop landings. (Second supervised solo.)

Period 16

Discuss, review, and practice crosswind takeoffs and landings, drift correction, use of flaps, and spot landings. Student will make at least four full stop landings solo. (Third supervised solo.)

Period 17

Discuss the use of radio in control of ground and air traffic. Student will practice takeoffs and landings as directed by the instructor. (Student will check radio prior to takeoff and will remain on the University frequency at all times while solo.)

Period 18

Written Stage 1 examination will be given by the instructor followed by a discussion of the results and appropriate recommendations.

Period 19

Stage check by the check pilot and discussion of student progress with appropriate recommendations.

Stage II: Pre-Cross Country

Post-Solo Proficiency Phase

Period 20

Introduce, discuss, and practice 720-degree steep turns and

recovery from power-on spirals visually and on instruments. Introduce shallow, medium, steep-banked turns to predetermined headings. Review takeoff and departure stalls, slow flight, and climbing and gliding turns.

<u>Period 21</u>

Introduce and discuss level standard rate turns to predetermined headings. Practice straight climbs and descents and climbing and descending turns.

<u>Period 22</u>

Discuss and practice visually and on-instruments recovery from spirals, slow flight, and approach to landing stalls. Review traffic pattern and takeoffs and landings.

<u>Period 23</u>

Instructor will brief student before takeoff. Student will leave pattern and practice takeoff and departure stalls, approach to landing stalls, 720-degree turns, slow flight, and accuracy landings. Student should check radio prior to takeoff and will remain on University frequency at all times while on local flight.

<u>Period 24</u>

Discuss, review, and practice all stalls, 720-degree steep turns, slow flight, and accuracy landings. Instructor should demonstrate use of omni on this flight.

<u>Period 25</u>

Review previous period and introduce short field and soft field takeoffs and landings.

<u>Period 26</u>

Discuss and practice maneuvers of Periods 24 and 25 as directed by the instructor. Simulated forced landings are strictly prohibited solo.

<u>Period 27</u>

Discuss and practice climbs, descents, climbing turns, and descending turns. Introduce "C" pattern in level flight. Practice turns to predetermined headings.

<u>Period 28</u>

Discuss and practice recovery from unusual altitudes. Practice

all variations of landings and takeoffs, soft field, short field crosswind, and full-stall landings.

Period 29

Discuss and practice maneuvers of previous periods as directed by the instructor.

Period 30

Discuss and practice "C" patterns and radio procedures.

Period 31

Give a thorough briefing on pecularities of night flying, the eye, and night vision. Student shall be made aware of good night-flying practices and precautions. Explain and demonstrate the Aldis lamp. Practice night landings.

Period 32

Written examination on State II will be given by the instructor and will be followed by a discussion of the results and appropriate recommendations.

Period 33

School check pilot. Complete proficiency check for Stage II with appropriate recommendations. Discussion follows check between check pilot, student, and instructor.

Stage III: Dual and Solo Cross-Country

Period 34

Discuss and practice at strange non-controlled and controlled airports such as Delaware, Columbus Air Park, and Port Columbus. Demonstrate and practice use of the omni. At least one landing will be made each at a controlled and non-controlled airport.

Period 35

Discuss map preparation, checking weather prior to takeoff, use of the computer, "Airmans' Information Manual," or other publications as necessary. The weather will be checked by use of teletype reports. The weather bureau will be called only if supplemental information is necessary. All landings will be made at airports served by a control tower. At least one visit should be made to control tower, weather bureau, and flight service station during the flight.

Period 36

The student should be checked on map preparation, flight-preparation knowledge of airports at which he will land, understanding of the anticipated weather he will encounter enroute plus additional forecasts and his plans in the event he becomes lost or is forced down because of weather. At least one destination should be served by a control tower. Flight should be planned over a triangular course, making full-stop landings, closing flight plan, re-filing a flight plan, and checking weather before departure on the next leg. (OSU - Dayton - Marion - OSU)

Period 37

Discuss the various aids to night navigation which shall include airway beacons, radio ranges, main highways, cities, forced landings, flare equipment, radar surveillance units, and "lost procedures." Flight experience shall include navigation by pilotage, radio range flying, and communications with a radar installation.

Period 38

Same as Period 36 except that one leg must be at least 200 miles non-stop from the University Airport. This flight will be made to Purdue University Airport, West Lafayette, Indiana and Baer Field, Ft. Wayne. Indiana.

Period 39

Give written examination of Stage III and discuss.

Period 40

School check pilot completion proficiency check for Stage III with appropriate recommendations.

Stage IV: Preparation for Course Completion Check

Period 41

Discuss and practice all stalls, 720° turns, climbing and gliding turns, slow flight, spirals, and high-altitude forced landings. The instructor should stress good planning on all flight, i.e., logical sequence of maneuvers, remaining within specified area, etc.

Period 42

Discuss and practice climbing and gliding turns, recovery from power-on spirals, turns to predetermined headings, recovery from unusual altitudes visually and on instruments.

Period 43

Discuss and practice maneuvers of Periods 41 and 42 as directed by the instructor.

Period 44

Discuss and practice complete "C" pattern and radio procedures.

Period 45

Discuss and practice all maneuvers to date with emphasis on those outlined in the FAA private-pilot flight test guide. Pay particular attention to flight planning and the use of the radio.

Period 46

Give final written exam and discuss. Record results appropriately.

Period 47

Instructor recommendation flight. Upon completion of flight, instructor completes student file.

Period 48

Final Flight Check

CRITERION FOR SAFE SOLO CROSS-COUNTRY

The following is a list of items that should be observed before a student is declared safe for solo cross-country. Make a note of the total flight time the student has and the date you make the decision the student is ready.

1. Safe for solo - local.

2. Demonstrate ability to control the aircraft through reference to instruments only.

3. Demonstrate ability to make at least three safe crosswind landings and recover from a bounced crosswind landing; make a traffic pattern pull up and go around; and enter a strange field.

4. Demonstrate ability to make "positive" identification of ground objects and use the proper procedures in locating the next check points.

5. Demonstrate ability to navigate by pilotage:

   a. Holding heading as pre-flight planned.
   b. Make small adjustment to headings, ground speeds, and ETA's after first wind check.
   c. Maintain altitudes.
   d. Set directional gyro from magnetic compass.

6. Demonstrate ability to navigate by VOR radio aids:

   a. Intercept a radial.
   b. Track within one-half needle deflection to within three minutes of station.
   c. Track outbound (same tolerances as 5c above).

7. Be capable of locating and checking NOTAMS pertinent to his planned route.

8. Understand communications procedures and demonstrate ability to accomplish effective in-flight communications, follow control tower instructions, and be encouraged to ask for information desired without fear.

9. Be able to locate all naviagation and communications frequencies to be used on a planned cross-country flight.

10. Capable of identifying reported or observed weather conditions which would be adverse to the continued safety of that flight.

11. Understand general procedures used in emergencies such as being lost, diverting to alternate field, and engine or mechanical malfunctions.

APPENDIX D

FLIGHT CHECK PROFILES

STAGE I FLIGHT CHECK

All flight students participating in the FAA programs, including ROTC, will be flight checked in the period immediately following an accumulation of 9.5 hours flight time. This time is not to include Ground Trainer nor the initial "taxi and engine run-up" orientation period.

The student will have the airplane selected, signed out, and pre-flighted. The check flight will be the same for all students and will adhere to the following profile as closely as possible:

Engine start
Radio check
Taxi clearance (Ohio State Ground, 121.7)
Taxiing
Engine run-up
Pattern check
Takeoff clearance (Ohio State Tower, 121.1)
Takeoff
Standard departure and climbout
Level off at 2500'
Turn to specific heading
Slow flight
Takeoff and departure stall
Approach to landing stall
Simulated emergency
Return to airport
Pattern entry
Landing
Taxiing
Shut down of aircraft

Flight time is estimated to be about 20 minutes. Results of the flight will be made available to the student by his instructor.

STAGE II FLIGHT CHECK

This flight check will be scheduled by the student's flight instructor when the instructor determines that the student is prepared to go solo cross-country. It is expected that this will occur after about 20 hours of total flight time.

This check flight will include cross-country planning and navigation. The flight maneuvers to be checked are:

Takeoff, departure, and climbout
Slow flight at minimum controllability
Steep turns
Departure stalls
Approach to landing stalls
Basic instruments
Emergency procedures
Short-field landings
Cross-wind landings

FINAL FLIGHT CHECK

This flight check will be the standard examination for private pilot certification and will adhere to the requirements and standards as contained in the Private Pilot Flight Test Guide, AC 61-3A.

The experimental students will take the flight check in an angle-of-attack-equipped airplane. The flight check will be conducted using the angle-of-attack instrumentation first, and then be immediately repeated with the angle-of-attack display made inoperative.

APPENDIX E

PILOT PERFORMANCE DESCRIPTION RECORD

Student:________________ Instructor:________________

Check Pilot:________________ Type Check:________________

Date:________________ Period No.:________________

Aircraft No.:________________ Hrs. Dual________ Solo________

Weather At beginning of flights:		At end of flight: ___Unchanged, or
Wind	___Headwind ___Slight crosswind ___Direct crosswind	___ ___ ___
Velocity	___Under 10 kts. ___10 - 15 kts. ___Over 15 kts.	___ ___ ___
Turbulence	___Calm ___Moderate ___Rough	___ ___ ___
Pattern traffic	___None ___1 - 3 planes ___More than 3	___ ___ ___
Runways used	__________	__________
Students Reactions	___Normal ___Nervous	___ ___
Other	__________	__________

PREFLIGHT

Key, magnetos and control lock check:

First thing Later Never

Walk around:	Proper	Sloppy	Forgot
Oil	☐	☐	☐
Gas Drain	☐	☐	☐
Hydraulic fluid	☐	☐	☐
Tires and brakes	☐	☐	☐
Aileron hinges	☐	☐	☐
Elevator hinges	☐	☐	☐
Rudder hinges	☐	☐	☐
Static airport	☐	☐	☐
Metal work	☐	☐	☐
Windshield	☐	☐	☐

COCKPIT PROCEDURES

Minor Errors	O.K.	Major Errors

RADIO PROCEDURES

Minor Errors	O.K.	Major Errors

TAXI PROCEDURES

Clearance from objects too close	O.K.	Exaggerated
Taxi Speed Slow	O.K.	fast
Use of brakes improper insufficient	O.K.	too much

RUNUP PROCEDURES

Check list followed__________ Checklist ignored___________

Minor Errors	O.K.	Major Errors

Clearing the traffic pattern before T.O.

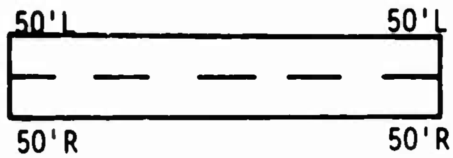
No turns_________ left turns_________ right turn_______

part way____ full 360°____

TAKE OFF

Normal X-Wind Short field Soft field

T.O. ROLL



Lift-off (or rotation) speed

50 55 60 65 70 75 80 85 90 95

Torque correction

rudder aileron

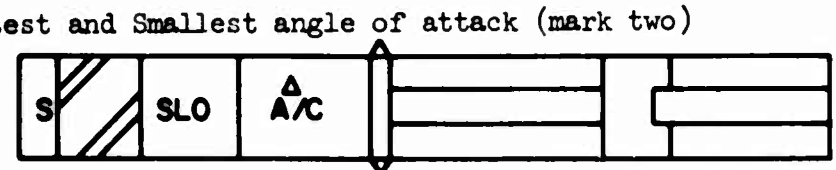
Runway alignment during climb

Left 0 Right

Lowest and Highest climb speed (mark two)

70 75 80 85 90 95 100 105 110 115

Greatest and Smallest angle of attack (mark two)



Pitch attitude during climb

too high constant too low hunting: little / a lot

Check for traffic

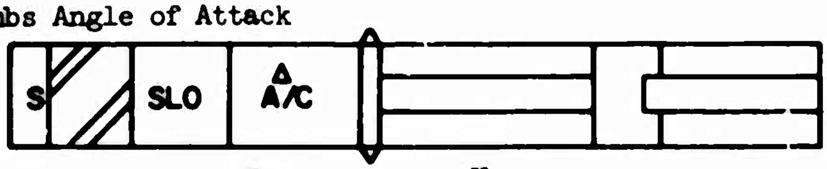
before turn during turn after turn

Traffic pattern exit correct incorrect

Climbs Airspeed

70 75 80 85 90 95 100 105 110 115 Variable

Climbs Angle of Attack



Clearing turns Yes______ No______

TRANSITION TO LEVEL FLIGHT

Power: correct________ incorrect________

Trim and altitude: correct________ incorrect________

STRAIGHT AND LEVEL FLIGHT

Altitude
200
100
0
100
200

Coordination: skid O.K. slip

Heading: 20° 10° 5° 0 5° 10° 20° R

Trim control: Holding back 0 forward Pressure

LEVEL FLIGHT TURNS (minimum 180°)

Altitude
200
100
0
100
200

Coordination: skid O.K. slip

Heading Error Recovery

20° 10° 5° 0 5° 10° 20° R

STALLS - APPROACH

Clearing turns: No Yes 2-90°'s 1-180°

Entry rate: slow proper fast

Torque control during entry: proper improper

Coordination: skid OK slip

Bank angle: shallow medium steep variable

Altitude change in the recovery:

200
100
50
0
50
100
200

Heading change:

10° 20° 30° 40° 50° 60° 70° 80° 90°

Pitch attitude at recovery: low proper high

Throttle control recovery:

early proper late

Carburetor heat control on recovery:

early proper late

Rudder usage in recovery:

too little proper too much

STALLS - DEPARTURE

Clearing turns: No Yes 2-90°'s 1-180°

Entry rate: slow proper fast

Torque control during entry: proper improper

Coordination: skid OK slip

Bank angle: shallow medium steep variable

Altitude change in the recovery:

200
100
50
0
50
100
200

Heading change:

10° 20° 30° 40° 50° 60° 70° 80° 90°

Pitch attitude at recovery:

early proper late

Throttle control recovery:

early proper late

Carburetor heat control on recovery:

early proper late

Rudder usage in recovery:

too little proper too much

STALLS - ACCELERATION

Clearing turns: No Yes 2-90°'s 1-180°

Entry rate: slow proper fast

Torque control during entry proper improper

Coordination: skid OK slip

Bank angle: shallow medium steep variable

Altitude change in the recovery:

200
100
50
0
100
200

Heading change:

10° 20° 30° 40° 50° 60° 70° 80° 90°

Pitch attitude at recovery: low proper high

Throttle control on recovery:

early proper late

Carburetor heat control on recovery:

early proper late

Rudder usage in recovery:

too little proper too much

SLOW FLIGHT AT MINIMUM CONTROLLABLE AIRSPEED

Transition into slow flight:

Throttle and pitch coordination: proper improper

Altitude change: -200 -100 0 100 200

Heading change: - 30° - 20° 0° 10° 20° 30°

Torque control: proper improper

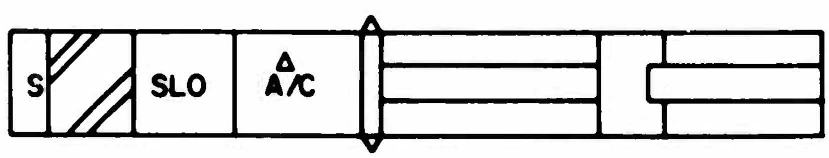
Airspeed:

50 55 60 65 70 75 80 85 90 Variable

Airplane actually stalled at:

40 45 50 55 60

Angle of Attack:



Transition out of slow flight:

Throttle and pitch coordination: proper improper

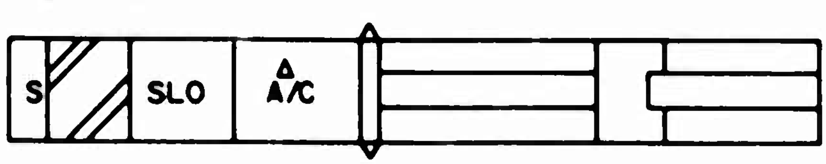
Altitude change: -200 -100 -50 0 50 100 200

Heading change: - 30° - 20° -10° 0° 20° 30°

Airspeed:

70 75 80 85 90 95 100 105 110 115 120

Angle of Attack:



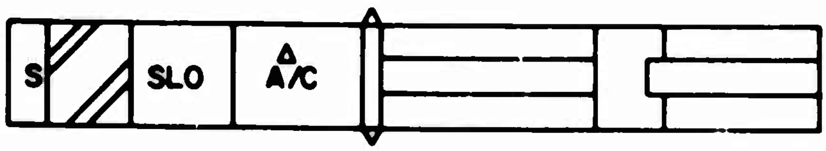
EMERGENCIES

High Altitude

Low Altitude

Airspeed: 70 75 80 85 90 95 100 105 110

Angle of Attack:



Selection of field: Proper Improper

A/C procedures: Proper Improper

Make the field: Yes No

DOWNWIND

Altitude:

200
100
50
0
50
100
200

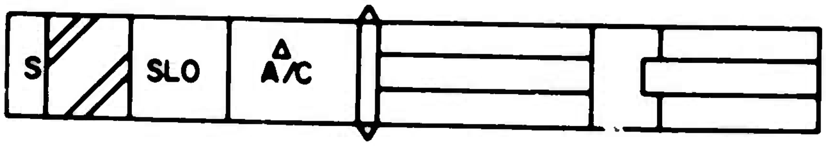
Heading:

20° 10° 5° 0 5° 10° 20° Variable

Airspeed:

75 80 85 90 95 100 105 110

Angle of Attack:



Carburetor Heat and Power Reduction

Early OK Late

Flaps: 1 2 3

TURN TO BASE AND BASE LEG

Indicated Altitude when turning on to base leg.

1400 1500 1600 1700 1800

Bank angle in this turn :

shallow medium steep

Coordination of the turn: skid OK slip

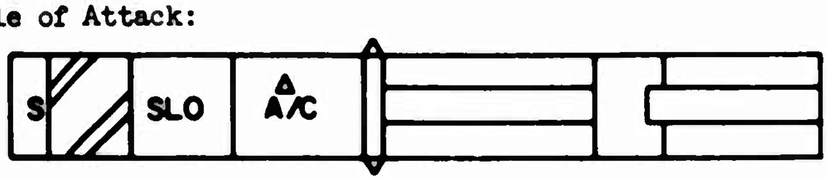
Heading:

-20° -10° -5° 0° 5° 10° 20° Variable

Airspeed on base leg.

65 70 75 80 85 90 95 100

Angle of Attack:



Pitch attitude: shallow steep

constant variable

Clearing of traffic: Yes No

Flaps: 1 2 3

TURN TO FINAL

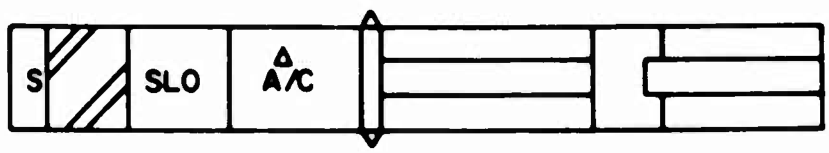
Timing: too soon OK too late

Coordination: skid OK slip

Clearing of traffic: yes no

A/S in turn: 60 65 70 75 80 85 90

Angle of Attack:



FINAL APPROACH COURSE

Type of landing: Normal X-Wind Short field Soft field

Alignment with runway: Left 0 Right

Pitch Attitude: shallow steep

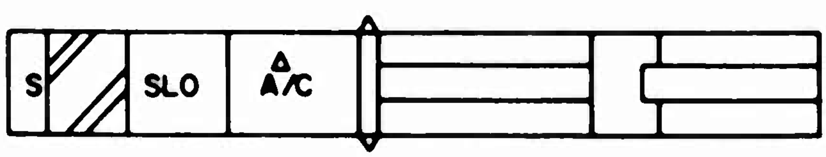
constant variable

X-Wind Correction: inadequate proper too much

Throttle control: too little 0 too much both

Airspeed: 60 65 70 75 80 85 90 95 Variable

Angle of Attack:



Flaps: 1 2 3

FLARE TO LANDING

Altitude: Low 0 High

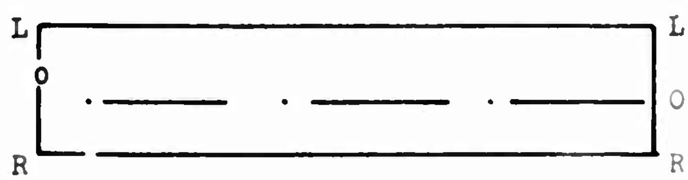
Runway alignment: Left 0 Right

TOUCH DOWN

Pitch attitude: Low 0 High V C

Impact: Light Medium Hard Bounce

ROLL OUT



APPENDIX F

A MODIFIED t STATISTICAL TEST

The experimental data in the form of flight check error scores presented a few difficulties for statistical analysis. The first was the smallness and variability of the sample size, varying from 6 to 10 for the uncombined groups. The second was the nonhomogeneity of sample variances. The third was the unavoidable loss of data for some students and some maneuvers.

In view of these problems, the validity of any sophisticated statistical analysis is weakened. It was therefore determined that a modified version of the standard t statistic be used.*

This statistic, t', has the property that when $\mu_x = \mu_y$, t' has an approximate t distribution. The probability distribution of t' has not been determined when μ_x does not equal μ_y.

The expressions for the t' statistic and the associated degrees of freedom, ν, are

$$t' = \frac{\bar{x} - \bar{y}}{\left[\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}\right]^{1/2}}$$

and

$$\nu = \left\{ \frac{\left[\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}\right]^2}{\frac{\left(\frac{s_x^2}{n_x}\right)^2}{(n_x+1)} + \frac{\left(\frac{s_y^2}{n_y}\right)^2}{(n_y+1)}} \right\} - 2$$

where

$\bar{x}$, $\bar{y}$ are the sample means,

s_x^2, s_y^2 are the sample variances, and

n_x, n_y are the sample sizes.

The standard single-tail t tables are used to determine the significance level.

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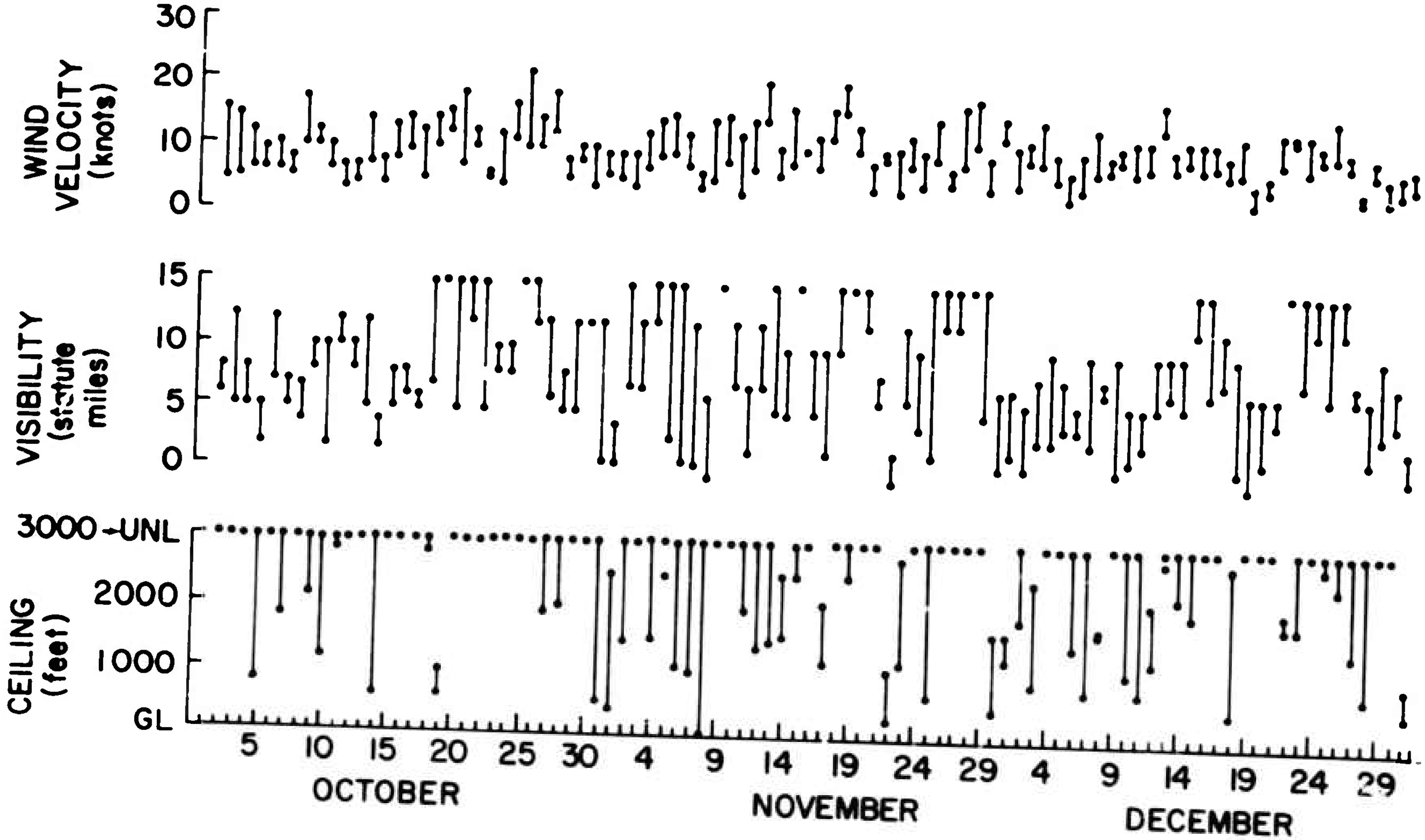
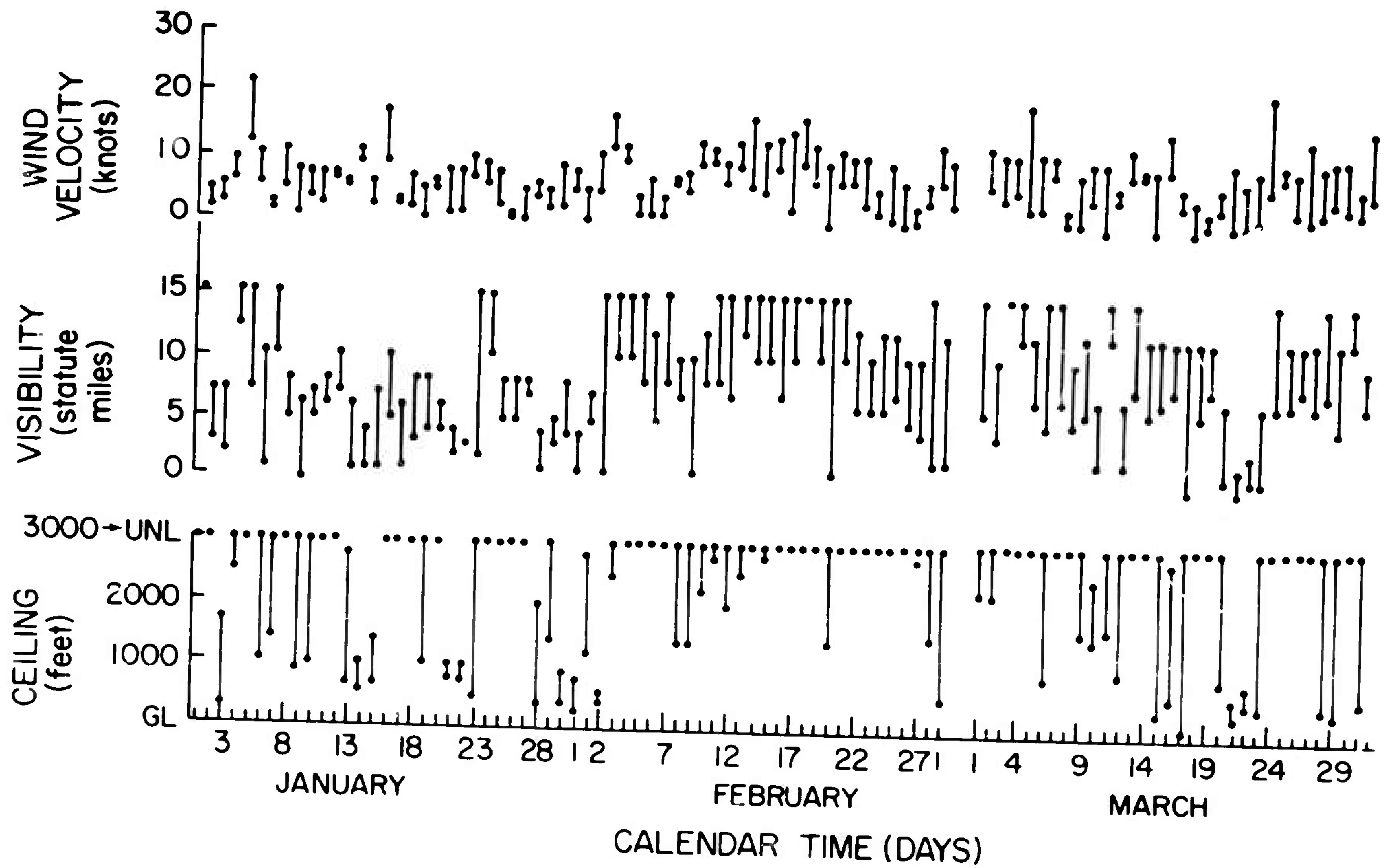
*Bowker and Leiberman, Engineering Statistics, Prentice-Hall, 1959, page 173.

APPENDIX G

SELECTED METEOROLOGICAL DATA - WEATHER CHARTS
(Autumn & Winter)



The dots when connected by lines indicate the range of the weather observations between the hours of 0700 and 1600



The dots when connected by lines indicate the range of the weather observations between the hours of 0700 and 1600

APPENDIX H

STUDENT BACKGROUND QUESTIONNAIRE

1. Name____

2. Address   Telephone No.
   Local____________________________________   Local________________

   Home_____________________________________   Home_________________

3. Age__________Birthdate______________________Place of Birth

   ____

4. Present Occupation___________________________Yrs. in occupation

   ____

5. Education:
   Years completed   High School_____________

   College_________________   ROTC__________

   Degrees received____________________________

6. Major and minor educational interest   Years in each

   a. ____   _____________

   b. ____   _____________

   c. ____   _____________

   d. ____   _____________

7. Major hobbies or extracurricular activities   Years in each

   a. ____   _____________

   b. ____   _____________

   c. ____   _____________

   d. ____   _____________

8. Please check and describe your involvement from the following list of activities.

   ______Automobile and motor repairs________________________________

_____ Sailing (describe the type of ships) _______________

_____ Motorboating (describe the moror types) _______________

_____ Skiing (water or snow) _______________

_____ Ice skating or roller skating _______________

_____ Dancing _______________

_____ Rifle or pistol shooting _______________

_____ Outdoor camping _______________

_____ Mountain climbing _______________

_____ Fishing _______________

_____ Other sports (please list and indicate your level of skill)

9. Military Service:

Branch _______________ Dates _______________

Highest rank _______________

Activities _______________

____

10. How did you become interested in flying?

____

____

11. How many hours have you flown in a light airplane?

As a student _______________ As a passenger _______________

12. What aviation ground school courses have you had or will be taking concurrently with your flying? (and dates)

a. _______________

b. _______________

c. _______________

d. _______________

13. What are your present intentions after you have learned to fly?

____

____

14. How many hours per week are you prepared to devote to:

Flight instructions ______________________________

Ground school instruction ________________________

15. If you have had previous flight instructions, what opinions do you have regarding the type of flight instructor you would like?

____

____

16. Without having previous flight instruction, how would you answer the above question?

____

____

17. Would you object to a female flight instructor? ______________.

APPENDIX I

Date ____________________

INSTRUCTOR QUESTIONNAIRE NO. 1

Name ______________________________ Certificate No. ____________

CFI Expiration Date ____________

Male Female Married Single

Age ________ Birthdate ____________________

Please check those which you have:

ATR	Commercial-Airplane	Flight Instructor-Airplane
	Land	Instruments
	Sea	Ground Instructor
	Single Engine	Basic
	Multi-engine	Advanced
	Instruments	Instruments

Current Total Flight Time ______________

Current Total Instrument Time: Simulated __________ Actual __________

Current Total Instruction given __________

Current Total Instrument Instruction given __________

Educational Degrees:

Major Subject:
Minor Subject:

Career Objectives:

Name(s) of your angle-of-attack students:

Name(s) of your control group students:

APPENDIX J

QUESTIONNAIRE NO. 4

Requires at most one hour
No books or other aids to be used

1. By using a diagram show the meaning of the following terms:

   Pitch angle
   Flight path angle
   Angle of Attack

2. Explain the term relative wind.

3. What is meant by angle of incidence?

4. What is the flight attitude of an aircraft when pitch angle, flight path angle and angle of attack are equal? (Assume angle of incidence = 0)

5. a. What is the aircraft's attitude when just the flight path angle and angle of attack are equal?

   b. For this condition what is the approximate value of the pitch angle?

6. List at least three maneuvers where the pitch angle and angle of attack remain constant (but not necessarily equal)

7. Discuss <u>briefly</u> the relationship between airspeed and angle of attack.

8. List some of the errors inherent in any angle of attack system.

9. List some of the errors inherent in the airspeed system.

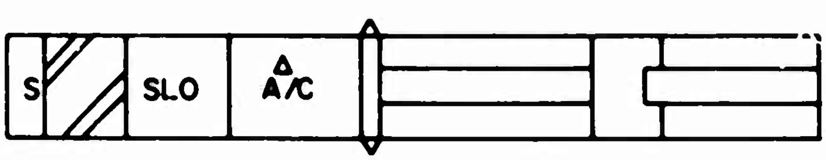
10. List those maneuvers which result in a different angle of attach value at the stall (assume the Cherokee 140)

11. a. Explain the meaning of "Slow Flight at Minimum Controllable Airspeeds".

    b. How would you determine this flight condition?

12. Complete the following table by placing the given numbers in A-O-A column on the appropriate place of the A-O-A scale. (control students to complete only the airspeed column)

	Angle of Attack	Airspeed Range
Rotation	1	
Initial climbout		
Best rate of climb	2	
Max angle of climb	3	
Cruise	4	
Slow flight at "minimum controllable Airspeed"		
No flaps	5	
Full flaps	6	
Entry to approach stall		
No flaps	7	
Full flaps	8	
Entry to depature stall (no flaps)	9	
Initial recovery from stalls	10	
Downwind leg	11	
Base leg		
Normal landing	12	
Short field landing	13	
Final leg		
Normal landing	14	
Short field landing	15	



13. Date(s) and score(s) of private pilot written examination.

14. How would you estimate your knowledge of the role of angle of attack and its use?

_____Excellent _____Good _____Poor

15. Do you feel you can display your understanding of it better

_____by performance in the airplane _____by discussion on the ground

16. Estimate the emphasis given by your instructor to your understanding of angle of attack.

________considerable
________same as for other things excluding airspeed
________same as for airspeed
________very little

17. How would you judge your instructor's knowledge of "angle of attack"?

________very good
________good
________not so good

Questions 18-27 apply only to the angle of attack students.

18. Estimate the value you received from the training manual on angle of attack.

_____of great value _____of some value _____of no value

19. How would you judge your instructor's attitude about the angle of attack system?

_____enthusiastic _____indifferent _____negative

20. How do you feel about the Angle of Attack System as an aid in your learning to fly?

___very good ___good ___not so good ___actually hindered

21. What maneuvers in your flight training do you feel it helped (if at all)? Check by numbers: 1 = most, 2 = next most, etc.

_____Takeoff and climbouts
_____Cruise flight
_____Slow flight　　　　　_____Not at all
_____Stalls
_____Approuches and landings

22. Where in your flight training do you feel it helped (if at all)? Check by numbers as in above question.

_____Pre-solo
_____Solo
_____Pre-cross country　　　　　_____Not at all
_____Cross country
_____Final preparation

23. Did you have any difficulty in using airspeed information?

_____yes　_____no
_____if yes, how so

24. Do you beleive you could fly with

Just angle of attack alone_____yes　_____no
Airspeed along　_____yes　_____no

25. If both angle of attach and airspeed information were available to you, estimate the relative value of their use in percentages?

_____angle of attack
_____airspeed

26. Did maintenance of reliability of the angle of attack system have any bearing on your progress?

_____no
_____yes, please describe

27. What opinions do you have regarding your involvement in this angle of attack program

_____constructive
_____informative only
_____indifferent
_____negative
_____other, please explain

____
Name

_______________ _______________ _______________
Date Time started Completed

APPENDIX K

INSTRUCTOR QUESTIONNAIRE NO. 2

1. Name ______________________________ Date ______________

   This form is to be completed for each of your control and/or experimental group stuents.

2. Student's Name ____________________ ______ Control
   ______ Experimental

3. Student's personality (as you know it).

Reserved	______________________	Outgoing
Less Intelligent	______________________	More Intelligent
Emotional	______________________	Stable
Humble	______________________	Assertive
Sober	______________________	Happy-Go-Lucky
Expedient	______________________	Conscientious
Shy	______________________	Venturesome
Tough-Minded	______________________	Tender-Minded
Trusting	______________________	Suspicious
Practical	______________________	Imaginative
Forthright	______________________	Shrewd
Placid	______________________	Apprehensive
Concervative	______________________	Experimenting
Group-tied	______________________	Self-Sufficient
Casual	______________________	Controlled
Relaxed	______________________	Tense
Low Anxiety	______________________	High Anxiety
Introversion	______________________	Extraversion
Responsive Emotionality	______________________	Tough Poise

Dependence	______________	Independence
Low Potential Leadership	______________	High Potential Leadership
Less Creative Personality	______________	Creative Personality

4. Student's Skill Aptitudes (as you know it).

Mechanics	Poor	______________	Superior
Self-Expression	Poor	______________	Superior
Physical Coordination	Poor	______________	Superior
Judgement of Distances	Poor	______________	Superior
Judgement of Angles	Poor	______________	Superior
Judgement of Sink Rate	Poor	______________	Superior
Depth Perception	Poor	______________	Superior
Sense of Speed (or speed change)	Poor	______________	Superior

RATE OF LEARNING

	Very quick needed no repetition	Quick; needed some repetition	Needed repetition on each flight but finally "got it"	Needed repetition. Never really "understood" but performed mechanically	Never understood. Unable to mechanically perform	Understood intellectually but unable to perform
Level flight and turns						
Transitions						
Trim control						
Stall series						
Slow flight						
Basic instruments						
Take-offs (regular						
Take-offs (short field						
Take-offs (soft field						
Landings (regular						
Landings (short field						
Landings (x-wind						
Airport patterns						
Flight planning						
X-C Navigation - VOR						
X-C Navigation - Pilotage & D.R.						
Emergency procedures						
General judgement						
Control coordination						
Radio communications						

6. How well do you beleive the student understands the following concepts? (Do not now discuss this with the student.)

	Very Well	Well	Not Well	Not at all
Rolling friction				
Induced drag				
Conditions to accelerate quickly				
Pitch attitude				
Flight Path Angle				
Angle of Attack				
Throttle control of (altitude				
Throttle control of (airspeed				
Pitch control of (altitude				
Pitch control of (airspeed				
Effect on Indicated Airspeed due to (gross weight				
Effect on Indicated Airspeed due to (bank angle				
Effect on Indicated Airspeed due to (temperature				
Effect on Indicated Airspeed due to (ambient pressure				

7. In teaching of slow flight, what flap setting do you normally use? ____________________;
what corresponding airspeed (or angle-of-attack) ____________;
What bank angle for level turns ____________________;

8. How do you define slow flight at minimum controllable airspeed?

9. In short field landings:

What flap setting sequence do you use?

What airspeed and/or angle of attack?

Where do you tell them to touch down with respect to the runway approach edge?

What criteria do you lay down for abort or "go-around" on the short field landings?

10. How would you generally describe the student's progress in light of your past experience?

	slow	fast	average	other
At first:	____	____	____	____________
Pre-solo phase:	____	____	____	____________
Solo phase:	____	____	____	____________
X-C phase:	____	____	____	____________
Final preparation:	____	____	____	____________

11. What influence did weather play in the progress of your student?

12. What influence did equipment failure (or unrealiability)play?

13. For the angle-of-attack students; (assume no malfunctioning)
   a) What is your general opinion of it?

   b) Where did you think it helped the student?

   c) Where did you think it hampered the student?

   d) How much do you beleive your own understanding of the device and its behavior have either helped or hampered your teaching?

   e) If available again in subsequent quarters, would you use it differently?________________________

   f) Do you feel you need more experience with the system to understand it better?____________________

   g) Would more in-flight demonstration and observation help?_____

   Or would a written manual on the subject suffice?___________

   Or both?________________

14. How closely do you feel you followed the school syllabus?

15. With what things in the school syllabus did you find the most difficulty? (In either following or teaching?)

APPENDIX L

SELECTED FLIGHT INSTRUCTOR COMMENTS

A number of questions on an Instructor Questionnaire asked for opinions regarding the role of weather and the angle-of-attack instrumentation. The pertinent comments are reproduced in this appendix.

<u>Question</u>: What influence did weather play in the progress of your student?

Instructor	Comments
I1:	C2 - Not too much; during the second week he encountered rough air, which alarmed him a bit
I2:	E4 - Weather slowed progress considerably
	E11 - No more than average
	E16 - Average - did not particularly hinder him
	C4 - Weather slowed progress considerably
	C11 - Average problems - no great factor
I4:	E* - Bad weather adversely affected his progress
I5:	E1 - Couldn't fly many times, sometimes 1 or 2 weeks
	E2 - Waited 3 weeks to go on long X.C.
I6:	C6 - Weather was a factor in my student's progress. There were occasions when it prevented my student from flying for several days
I7:	E6 - Some due to poor weather conditions existing for his solo X.C.
	C5 - Not as much as the fact that the student was out for $2\frac{1}{2}$ weeks with a stomach ulcer
I9:	E7 - A good deal because the student was slow to solo; after solo not much
	C8 - Some
	E11 - A great deal
I10:	E1 - None, except student was unable to finish the 38 hours in one quarter's time
	C1 - Bad weather forced us to fly more in the last week of the quarter than was anticipated

E*These students did not complete the program.

I13: E15 - There were a great many days when we were unable to fly because of weather, this probably slowed the student's progress

C9 - Bad weather hindered progress

Question: What influence did equipment failure (or unreliability) play?

I2: E4 - The angle of attack made it impossible to use it as consistently as desirable

I3: E* - Considerable

I4: E* - Inoperative angle-of-attack adversely affected his progress

I5: E1 - When our plane was grounded there were rarely others available and these had differences in the indicators that caused some confusion

E2 - Bad influence - couldn't fly many times because our plane was grounded and the others were flying. When we did fly another plane, the angle-of-attack instruments were very different so the student often was confused in the various settings

I6: C6 - At first this was a factor, however, as the quarter moved on, it no longer was a factor

I7: E6 - Very little - possibly two days lost

I9: E7 - A good deal in the beginning because the angle-of-attack instrument was not always reliable

E11 - A great deal

I16: E6 - None (equipment good)

E14 - None

Question: For the angle-of-attack students (assume no malfunctioning)

(a) What is your general opinion of it?

(b) Where did you think it helped the student?

(c) Where did you think it hampered the student?

(d) How much do you believe your own understanding of the device and its behavior have either helped or hampered your teachings?

I1: E3 - (a) It is of some training value

E* These students did not complete the program.

(b) Demonstrating angle-of-attack, slow flight, turns, stalls, etc.
(c) Didn't hamper the student
(d) I don't believe it hampered; I feel I understand the instrument

E5 - (a) Rather unneeded on Cherokee-type planes
(b) In demonstrations of slow flight, stall, steep turns, G-factors, etc.
(c) Never actually hampered the student
(d) I feel I understood the instrument; it helped

E9 - (a) Generally, it's a good instrument which gives very practical information
(b) It helped a comprehension of the concept of angle-of-attack
(d) Little

I2: E4 - (a) OK generally
(b) Takeoffs and landings
(c) It is no help in cruise or transitions
(d) My complete unfamiliarity with the instrument made my attempt to instruct with it very ineffective

E11 - (a) Very good
(b) In slow flight and landings and general understanding of why certain things happen
(c) I saw no hindrance at all
(d) It has helped a great deal even with control and non-program students

E16 - (a) Very good
(b) On slow flight - landings - understanding why certain things happen
(c) I saw no hindrance at all
(d) It has helped a great deal even on control and non-program students

I3: E* - (a) Nothing to write home about. Good if optimum performance is desired
(b) Didn't
(c) Both airwork and pattern
(d) Neither

I5: E1 - (a) Should be used to back up the airspeed
(b) Seeing how the plane stalls in different attitudes and airspeeds
(c) Smoothness
(d) I could have presented it more effectively if I could have observed other competent people

---

E* These students did not complete the program.

E2 - (a) I think it should only be used as a back-up instrument used in conjunction with the airspeed.
(b) Seeing how the plane stalls in different attitudes and airspeeds
(c) On smoothness
(d) I understood it fairly well; however, I wasn't sure on how to teach it effectively

I7: E6 - (a) I believe that it is a benefit to beginning students, however, it seems to neither add to or detract from further learning past 15 to 20 hours of instruction and it has no use as far as I can see in instrument instruction. It appears to be an excellent aid when one is concerned with optimum performance of one aircraft; however, I believe the average private pilot has no real use for such performance.
(b) It helped to demonstrate how, by changing the attitude of the airplane, it would climb, descend, or remain at cruise; also aided in demonstrating the loss of vertical lift component in turns and stalls
(c) Sometimes student fixated on it and would change the pitch attitude too fast for the angle-of-attack meter to catch up. Also, my student commented that after 15 hours he did not rely on the meter any longer
(d) In some ways my teaching of this device to the student was hampered because it was not explained to me properly in the first place; however, a thorough understanding aids in the presentation of this device

I9: E7 - (a) Good reference instrument only
(b) Pitch attitude
(c) At the start because of its unreliability
(d) Not much

E11 - (a) Good reference instrument only
(b) In pitch attitude
(c) At the start because of its unreliability
(d) Not much

I10: E1 - (a) Useful in some areas for student
(b) In stall series, slow flight, and steep turns
(c) On approaches and landings - angle-of-attack lagged behind airplane and airspeed indicator
(d) None

I11: E8 - (a) Value is limited
(b) Don't think it did
(c) None outside of mechanical failure
(d) My lack of experience and briefing in use of angle-of-attack hampered, at least to a slight degree, the student

I12: E17 - (a) OK
(b) No factor
(c) No factor
(d) It didn't

I13: E15 - (a) It's a good instrument and a good teaching aid
(b) I think it helped the student understand the relationship of various aircraft configurations (power, flaps, etc.) to angle-of-attack much better than diagrams or verbal descriptions
(c) I don't think it did hamper the student
(d) The instrument enabled me to see angle-of-attack in action and therefore helped me explain angle-of-attack better

I14: E10 - (a) Great
(b) In understanding basic aerodynamics
(c) Rotation
(d) Help if anything

I15: E12 - (a) Great
(b) Slow flight, approaches
(c) Aircraft limitations, early stall recovery
(d) Not really injured, but I wasn't satisfied

I16: E6 - (a) Good
(b) Stalls at beginning and final prep slow flight-approaches
(c) Didn't
(d) Should have known more

APPENDIX M

SELECTED OBSERVER COMMENTS

COMMENTS BY THE DEPARTMENT OF AVIATION'S CHIEF FLIGHT INSTRUCTOR

Organization and Administration

It would have been advisable to have had the equipment that was used in the latter part of the program, or second quarter, at least one quarter in advance of the time we started the project. This would have enabled our flight instructors to fly a group of students with the equipment prior to the start of the project. As a result we would have been better able to train beginning students using the angle-of-attack indicators. Since this type of indicator had not been used before in primary training, there was a period of experimentation and mistakes in instructional techniques which could have been avoided had we been able to use the equipment before starting the project. We thought initially that sufficient checkout procedures had been established, but we found it necessary to change techniques after getting into the program. The angle-of-attack equipment used during the second quarter was much better and much more reliable than that used the first quarter. In fact, most instructors stated the new angle-of-attack indicators were much better than the airspeed indicators.

Communications

Problems in communications stemmed mainly from the fact that there was not complete understanding initially by all persons concerned as to how the angle-of-attack indicator was to be used. I beleive, however, this problem was straightened out during the second quarter and there were few problems in communications.

Standards

Standards for flight checks were the same as required for any primary students. A check procedure was established that, in my opinion, did a good job of determining student performance. The chief flight instructor did the majority of the checks prior to the final check ride, therefore, differences because of several check pilots should have been minimized.

Flight Performance

I believe there were detectable differences in the way the experimental group performed in the early stages of flight training. They were better able to cope with climb and descent attitudes and there was generally less hunting or chasing of these attitudes. Climbouts after takeoff were much better, with little or few changes in pitch. This

was especially noticeable at the stage I check flight when students in general have a tendency to over control. Approaches to the airport were steadier in respect to pitch and there was a definite tendency for the experimental group to have a lower indicated airspeed on the approach than the students in the control groups. As a matter of fact I have the feeling from observation, but cannot verify, that speeds among all our students on approaches were reduced as a result of the experimental group using the angle-of-attack instruments. Prior to this we have had some problems with students using too fast an approach to landings. Instructors may have found that the aircraft can be flown safely at slower airspeeds on the approach to a landing, thus affecting the performance of all students.

It was definitely proved and agreed upon by everyone that the airspeed indicator is a rather inaccurate method of measurement. Another area that might show some difference is the area of slow flight or flight at minimum controllable airspeed. I do not recall at this time whether there was a marked difference between the control students and the experimental groups. Toward the end of the program the differences in the students evened out with the exception that the experimental group consistently flew slower approach speeds than the control group. This was especially true in the short-field landing phases. I would say also that it seemed as though their approach path on the short-field landing was generally better than that of the control group. This was because usually the attitude of the aircraft was more consistent, with fewer changes in pitch and angle of attack.

Maintenance

Maintenance of the original equipment installed the first quarter was a problem. When cold weather came, we had difficulties because of instruments sticking.

This sticking caused some problems and erratic readings. As a result it was difficult for the instructor and students to trust or to rely completely on the instrument readings. In addition there were other difficulties in the maintenance of the angle-of-attack indicators, vanes, and other components. The second quarter after the new equipment was installed the angle-of-attack indicator seemed to work almost entirely free of error and very few problems were encountered. One or two of the vanes were broken and whether this was because of moving aircraft in the hangars or other reasons is not known. The vanes were covered with protective hoods when hangared. This was not a problem since parts were readily accessible and easily replaced. Other than this, I do not know of any difficulties experienced in the working of the equipment. I am sure the new set containing the new dial was much better and easier to read than the initial equipment used the first quarter.

Training

The students selected seemed to be a reasonable sampling of those the Department of Aviation normally trains in any given time. Some students were quite good, and of course, there were a few that were not good. I feel that, especially for the second quarter, the use of the angle-of-attack equipment was helpful and the students enjoyed using it. The instructor and student relationships were very good and every effort was made on the part of both instructors and students to use the angle-of-attack indicators to the best advantage for the purposes of this project.

Weather

Weather during the Autumn quarter was a serious problem and prohibited us from finishing on schedule. In addition, the weather during the first part of the Winter Quarter, the month of January especially, was too bad for initial training. As a matter of fact there was one week in January when we failed to fly because of low ceilings and precipitation consisting of snow and rain. Toward the middle and the end of the Winter Quarter, however, the weather did improve and we were able to proceed with our training program. We were, however, considerably behind schedule.

Training aids

It might have been advantageous in the beginning of the project or the first quarter to have had training aids in the form of mock-up or film about the angle-of-attack equipment and its usage. However, there was nothing available to our knowledge concerning the use of this equipment in a primary training program. We employed the usual training aids which we have in our primary work, and which involved film and the use of ground trainers. The use of the ground trainer did not seem to make any difference as far as the angle-of-attack students were concerned.

COMMENTS BY THE DEPARTMENT OF AVIATION'S FAA DESIGNATED EXAMINER

In the course of examining students for a private pilot certificates, as a designated pilot examiner, I have tested many of the angle-of-attack students involved in the experimental program. For data collection purposes, each student performed the flight maneuvers required for the private certificate with the angle-of-attack indicator operating; then the maneuvers were repeated with the indicator turned off in order to comply with FAA regulations covering flight test procedures.

The differences between individual performances with and without the angle-of-attack indicator are, in my judgment, very slight. There were two instances that impressed me as being significant. One student

using the angle-of-attack device was excuting a simulated emergency landing. His last turn to the field was low and the bank steep, a situation that can rapidly become hazardous. However the student held the angle-of-attack indicator in the proper place and turned smoothly with no loss of airspeed. The second case occurred during landings with the angle-of-attack instrumentation turned off. The student began chasing the airspeed and consequently made a poor approach and a hard landing. The students using the angle-of-attack indicator consistently made their final approaches at a slower airspeed than those not using the device.

It must be noted here also that the students being tested for the private certificate had been practicing the required maneuvers without the angle-of-attack device in the latter stages of the program and may have lost some of their originally gained proficiency with the instrument.

I would say the differences between an angle-of-attack student and a non angle-of-attack student at the private pilot proficiency level are impossible to detect with any degree of confidence.

NARRATIVE BY THE PRINCIPAL OPERATIONS INSPECTOR FROM THE FAA GENERAL AVIATION DISTRICT OFFICE AT COLUMBUS

This report is an evaluation of angle-of-attack student E9 conducted in visual flight conditions at The Ohio State University Airport, Columbus, Ohio, on March 28, 1968. Weather condition was light to moderate turbulence. Aircraft used was Piper PA-28, N190SU. Flight time was 42 minutes.

Takeoff

There was a slight crosswind on Runway 23. Applicant maintained proper heading and rotation was normal. He established the proper drift correction and attitude on the climb out. Traffic exit was also satisfactory.

Flight at Minimum Controllable Airspeed

Throttle and elevator coordination were good and he established the minimum speed using good trim and control techniques. Heading was maintained within 10° and altitude varied from 50 feet above to 50 feet below his altitude. During the recovery to straight and level flight normal crusie, the applicant decended 100 feet below his altitude.

Departure Stalls

Executed in a satisfactory manner with only minor errors noted in coordination. Procedures were good.

Approach to a Landing Stall

Executed in a satisfactory manner with only minor errors noted in coordination. Procedures were good.

Accelerated Stalls

Good techniques and satisfactory aircraft control were used and the heading change was 30° with a gain of 50 feet in altitude. Again the applicant used good procedures and maintained good command of the aircraft.

Steep Turns (Right)

Excuted with a 45° bank and was maintained fairly constant. Coordination was fair with only a mild slip resulting. In 360° of turn the applicant gained 100 feet.

Emergencies

A high-altitude forced landing was given to the student and he used good procedures, selected a good field, maintained a constant pitch attitude. His maneuvering to final approach was very good and he would have made to field.

Traffic Pattern

The applicant entered the traffic pattern properly and committed only minor errors in altitude control and heading control on downwind and base legs. His turn to final was satisfactory. On the first landing the applicant performed satisfactorily and in fact used good techniques. On the second landing the applicant leveled off high and continued with the landing process to a point that the inspector was required to apply power and stop the student's control action. Condition at the time was wind 15 knots with gusts. At the time the inspector made the corrective action the angle-of-attack instrument was in the slow edge of the yellow range with a high rate of descent. In the post-flight briefing, the applicant was quizzed as to his actions and he stated that he had not been cross checking the angle-of-attack instrument nor was he congnizant of the visual attitude of the aircraft, and that he was concentrating on the airspeed indicator. When quizzed as to why he was not cross checking the angle-of-attack indicator, he stated that he was getting up to a point near his private pilot test and that he was trying to rely on the airspeed indicator in preparation for the test in anticipation of taking the test in an aircraft not equipped with an angle-of-attack indicator.

APPENDIX N

DESCRIPTION OF THE APTITUDE AND PERSONALITY TESTS

The following tests were voluntarily taken by most students in the program. The tests were to be taken within the first week of flight training. The descriptions which follow are limited to statements of purpose and are extractions from the test's manual of directions.

Otis: Gamma

This test attempts "to measure mental ability, thinking power, or the degree of maturity of the mind." It is a timed test, allowing 30 minutes. The norm for adults (age 18 or over) is 42.

Owens-Bennett Mechanical Comprehension Test - Form CC

This test "is designed to measure the ability of an individual to understand various kinds of physical and mechanical relationships. The capacity to recognize the causal relationships involved in these problems is of value in courses in engineering, physics, chemistry, mathematics, and most branches of mechanics. Military experience has shown that mechanical comprehension is valuable for those engaged in the operation and maintenance of complex mechanical devices. There is no time limit, but little is gained by allowing more than forty-five minutes." The norm for college seniors is 47.

Flanagan Aptitude Classification Tests

Selected tests from the complete Flanagan ACT battery were given.

Test 1 - Inspection:
Ability to spot flaws or imperfections in a series of articles quickly and accurately. Maximum score is 80.

Test 7 - Judgment and Comprehension:
Ability to read with understanding, to reason logically, and to use good judgment in practical situations. Maximum score is 24.

Test 9 - Planning:
Ability to plan, organize, and schedule; ability to foresee problems which may arise and to anticipate the best order for carrying out the various steps. Maximum score is 32.

Test 15 - Alertness:

Ability to perceive a dangerous situation and to identify the specific action that is needed. Maximum score is 36.

Cattell-Eber Sixteen Personality Factor Test

This test "is a factor analytically developed personality questionnaire, designed to measure the major dimensions of human personality comprehensively in young adults and adults from 16 or 17 years to late maturity." There is no limit, but 60 minutes appears to be adequate. A copy of the score sheet is attached and is self explanatory.

16 P F TEST PROFILE

LOW SCORE DESCRIPTION	Factor	RAW SCORE	Standard Score	STANDARD TEN SCORE (IN STENS)*	HIGH SCORE DESCRIPTION
RESERVED (Sizothymia)	A	6	2.1		OUTGOING (Cyclothymia)
LESS INTELLIGENT (Low "g")	B	8	8.0		MORE INTELLIGENT (High "g")
EMOTIONAL (Low ego strength)	C	19	7.0		STABLE (High ego strength)
HUMBLE (Submissiveness)	E	8	4.7		ASSERTIVE (Dominance)
SOBER (Desurgency)	F	20	8.8		HAPPY-GO-LUCKY (Surgency)
EXPEDIENT (Low superego)	G	11	4.2		PROPER (High superego)
SHY (Threctia)	H	14	6.2		VENTURESOME (Parmia)
TOUGH-MINDED (Harria)	I	6	1.6		TENDER-MINDED (Premsia)
TRUSTING (Alaxia)	L	6	4.8		SUSPICIOUS (Protension)
PRACTICAL (Praxernia)	M	14	6.3		IMAGINATIVE (Autia)
FORTHRIGHT (Artlessness)	N	13	7.3		SHREWD (Shrewdness)
PLACID (Assurance)	O	9	4.8		APPREHENSIVE (Guilt proneness)
CONSERVATIVE (Conservatism)	Q_1	12	7.9		EXPERIMENTING (Radicalism)
GROUP-TIED (Group adherence)	Q_2	14	7.7		SELF-SUFFICIENT (Self-sufficiency)
CASUAL (Low integration)	Q_3	10	4.3		CONTROLLED (High self-concept)
RELAXED (Low ergic tension)	Q_4	6	3.0		TENSE (Ergic Tension)

A sten of	1	2	3	4	5	6	7	8	9	10	is obtained
by about	2.3%	4.4%	9.2%	15.0%	19.1%	19.1%	15.0%	9.2%	4.4%	2.3%	of adults

	STANDARD SCORE	SECOND-ORDER FACTORS AND DERIVATIVE PREDICTIONS (IN STENS)	
INTROVERSION (Invia)	6.0		EXTRAVERSION (Exvia)
ADJUSTMENT OR LOW ANXIETY	4.1		HIGH ANXIETY
RESPONSIVE EMOTIONALITY (Pathemia)	10.		ALERT POISE (Cortertia)
SUBDUEDNESS OR DEPENDENCE	8.3		INDEPENDENCE
LESS NEUROTIC TREND	1.4		MORE NEUROTIC TREND
LESS LEADERSHIP POTENTIAL	7.3		MORE LEADERSHIP POTENTIAL
LESS CREATIVE PERSONALITY	6.1		CREATIVE PERSONALITY

Scored by NATIONAL COMPUTER SYSTEMS 1015 So. 6th, Minneapolis, Minn. 55415

* See Supplement of Norms for centile equivalents

BRIEF DESCRIPTION OF WHAT THE 16 PF MEASURES

The Primary Factors

Factor	A person with a low score on ↓ is described as:	A person with a high score is described as:
A	**RESERVED,** detached, critical, cool	**OUTGOING,** warmhearted, easy-going, participating
B	**LESS INTELLIGENT,** concrete-thinking	**MORE INTELLIGENT,** abstract-thinking, bright
C	**AFFECTED BY FEELINGS,** emotionally less stable, easily upset	**EMOTIONALLY STABLE,** faces reality, calm
E	**HUMBLE,** mild, obedient, conforming	**ASSERTIVE,** independent, aggressive, stubborn
F	**SOBER,** prudent, serious, taciturn	**HAPPY-GO-LUCKY,** heedless, gay, enthusiastic
G	**EXPEDIENT,** a law to himself, by-passes obligations	**PROPER,** overly conscientious, persevering, staid, rule-bound
H	**SHY,** restrained, diffident, timid	**VENTURESOME,** socially bold, uninhibited, spontaneous
I	**TOUGH-MINDED,** self-reliant, realistic, no-nonsense	**TENDER-MINDED,** dependent, over-protected, sensitive
L	**TRUSTING,** adaptable, free of jealousy, easy to get on with	**SUSPICIOUS,** self-opinionated, hard to fool
M	**PRACTICAL,** careful, conventional, regulated by external realities, proper	**IMAGINATIVE,** wrapped up in inner urgencies, careless of practical matters, bohemian
N	**FORTHRIGHT,** natural, artless, sentimental	**SHREWD,** calculating, worldly, penetrating
O	**PLACID,** self-assured, confident, serene	**APPREHENSIVE,** worrying, depressive, troubled
Q_1	**CONSERVATIVE,** respecting established ideas, tolerant of traditional difficulties	**EXPERIMENTING,** critical, liberal, analytical, free-thinking
Q_2	**GROUP-DEPENDENT,** a "joiner" and good follower	**SELF-SUFFICIENT,** prefers own decisions, resourceful
Q_3	**CASUAL,** careless of protocol, untidy, follows own urges	**CONTROLLED,** socially precise, self-disciplined, compulsive
Q_4	**RELAXED,** tranquil, torpid, unfrustrated	**TENSE,** driven, overwrought, fretful

Second-Order Factors and Derivative Predictions

SECOND-ORDER, "BROAD" TRAITS

EXTRAVERSION -VS.- INTROVERSION
A high score indicates a socially out going, uninhibited person, good at making contacts, while the low score indicates an introvert, both shy and self-sufficient.

ANXIETY -VS.- ADJUSTMENT
The score shows the level of anxiety in the commonly accepted sense, which may be either manifested for normal situational reasons or may be neurotic in origin.

ALERT POISE -VS.- RESPONSIVE EMOTIONALITY
High "alert poise" scores indicate an enterprising, decisive, imperturbable personality. The low score points to a person more deeply emotionally sensitive guided by emotions, and liable to more frustration and depression.

INDEPENDENCE -VS.- SUBDUEDNESS
High scores betoken an aggressive, independent, self-directing person, low scores, a group-dependent, agreeable, passive personality.

CRITERION PREDICTIONS

NEUROTIC TREND
A high score indicates closeness to the personality of clinically-diagnosed neurotics. A low score indicates absence of neurotic difficulties.

LEADERSHIP
A high score indicates the type of person elected to leadership in face-to-face groups, a low score, a person who would not naturally tend to come to a leadership position.

CREATIVITY
High score shows the type of personality which is creative and inventive in any area in which he possesses the ability and training, that is, the general tendency to work creatively in science, literature, art, or the every day job, etc., regardless of field. Creativity, in contrast to routine efficiency, is, of course, not necessarily desirable in many occupations.